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ID3 - Course book

Unit ID3: Do – Controlling workplace safety issues

Learning outcome 10:

You will be able to advise the organisation on a range of common workplace safety issues/hazards including how these can be assessed and controlled.

10.1: Safe work environment

Practical considerations in providing and maintaining safe places of work and safe means of access and egress

ILO recommendation R164 and convention C155 state "*Employers shall be required to ensure that, so far as is reasonably practicable, the workplaces, machinery, equipment and processes under their control are safe and without risk to health*."

A "*workplace*" is defined as anywhere workers need to be or to go by reason of their work and which are under the direct or indirect control of the employer.

For example:

- An engineer in a workshop
- An administrative worker in an office
- Workers in cold stores
- Workers on a construction site
- Operators on offshore oil and gas installations

Examples of workplaces

Whilst the types of workplaces are different the employer, in all cases, must take reasonable steps to ensure that the workplace is safe and remains so.

The UK HSE states examples of steps an employer may need to take to ensure the safety of the workplace.

They include:

- Make sure buildings are in good repair.
- Maintain the workplace and any equipment so that it is safe and works efficiently.
- Put right any dangerous defects immediately or take steps to protect anyone at risk.
- Take precautions to prevent people or materials falling from height, e.g. fencing or guard rails.
- Have enough space for safe movement and access (people and vehicles).
- Make sure floors, corridors, and stairs are free of obstructions (e.g. trailing cables) or spillages.
- Provide good drainage in wet processes.
- Make sure all windows and skylights are designed and constructed so that they may be cleaned safely (you may also need to fit anchor points if window cleaners have to use harnesses).
- Minimise risks caused by snow and ice on outdoor routes, e.g. use grit, salt, or sand, and sweep them.

Safe Access and Egress

Safe access to, and egress from, the workplace are fundamental aspects to the safe working conditions that should prevail within any workplace. Access and egress means the route through or means of entry to (or exit from) a workplace.

As previously mentioned, A "*workplace*" is defined as anywhere workers need to be or go by reason of their work and which are under the direct or indirect control of the employer.

Examples of safe access requirements encountered in a workplace include:

- Pedestrian pavement access into an office block.
- Vehicle road access into a refinery, segregated from pedestrian movements.
- Separate pedestrian and forklift truck access doors into a warehouse.
- Ladder access to a scaffold or excavation.
- Adequate man-way access into a confined space.

Workers should be able to gain access to all parts of the workplace with minimal risk of tripping, falling, getting trapped, or striking fixed objects.

Ways in which this can be achieved include:

- Providing ladders. Especially long ladders (such as inside wind turbines) can be fitted with hoops or platforms for the worker to stop and rest.

- The provision of fall arrest or fall restraint systems.
- Provision of guardrails, barriers, or self-closing gates.
- Eliminating steps outside of doors, which can take a pedestrian by surprise.
- Ensuring the floor remains free of slip and trip hazards.

Safety Signs in the Workplace

Employers should only install safety signs to warn of a hazard, or course of action, to control a significant risk when there is no other reasonable option. Before installing safety signs the employer should examine whether the hazard can be eliminated, avoided, or reduced by other means such as engineering controls (for example reducing noise at source by modifying a piece of equipment).

Safety signs give a specific message to those who may be exposed to hazards in the workplace. The message may be to identify hazards, to provide information on how to protect yourself, to indicate the location of safety and fire protection equipment, or for giving guidance and instruction in an emergency.

To avoid confusion as a result of language or reading difficulties, the shape, symbol, and colours used for safety signs should be to a standardised format so that the message is conveyed to the workers without the need for written text (text may be optional). Whilst the format of safety signs may vary slightly around the world, the principles are similar.

ISO 7010, *Graphical symbols - Safety colours and safety signs - Registered safety signs* is an international standard for consistent safety sign regulation across Europe.

"ISO 7010:2011 prescribes safety signs for the purposes of accident prevention, fire protection, health hazard information and emergency evacuation. The shape and colour of each safety sign are according to ISO 3864-1 and the design of the graphical symbols is according to ISO 3864-3."

Categories of Sign

There are 5 basic categories of sign, each with its own distinctive shape and colours, as follows:

- Prohibition
- Warning
- Mandatory
- Escape routes and safety equipment (safe condition)
- Fire equipment

The categories are shown in the image that follows. Note that the text shown in the examples is optional.

Shape	Meaning	Colour	Examples
	Prohibition	**RED** (contrast: white)	No smoking
	Mandatory action	**BLUE** (contrast: white)	Wear Eye protection
	Warning	**YELLOW** (contrast: black)	Danger Flammable material
	Information about safe condition	**GREEN** (contrast: white)	Escape Route
	Fire safety	**RED** (contrast: white)	Fire Extinguisher

Safety signs should be located in the line of sight at a suitable height and position. They may be located at the access to a general hazard area (for example entrance to a noisy compressor room) or next to a specific hazard (such as a wet floor, or an electrical hazard).

Employers must ensure that:

- Signs are maintained. Any defective or faded signs should be replaced.
- Workers, and others working on the premises, are instructed as to the meaning of the signs and actions to be taken in connection with them.

The USA, and countries that adopt the US approach, may use a different structure. Two agencies govern safety signs and marking, OSHA and ANSI. Pre- 2103 (under ANSI Z35) there were 3 classifications of safety sign:

- *Danger signs*: indicate immediate danger and that special precautions are necessary. OSHA specifies that red, black, and white colours are to be used for danger signs.

- *Caution signs*: warn against potential hazards or caution against unsafe practices. OSHA specifies that caution signs must have a yellow background and black panel with yellow letters. All letters used against the yellow background must be black.

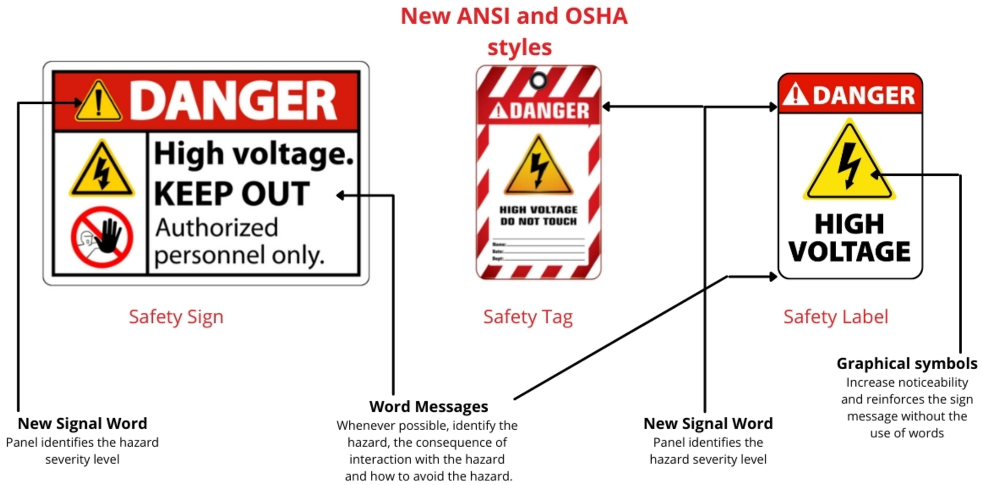
- *Safety instruction signs*: must be used where there is a need for general instructions and suggestions relative to safety measures. OSHA specifies that safety instruction signs must have a white background, green panel, and white letters. Any letters used on the white background must be black.

In 2013 OSHA adopted the ANSI Z535-2011 standard for safety signs, making both newer ANSI formats and the older formats (thought of as OSHA formats) permissible under OSHA standards. Under ANSI Z35 there are eight classifications of signs.

These are:

- Danger
- Warning
- Caution
- Notice
- General safety
- Fire safety
- Directional arrow signs
- Special signs

Examples and comparisons of the new and old signs follow:



New Format
ANSI-Z535.2-2011 Standard

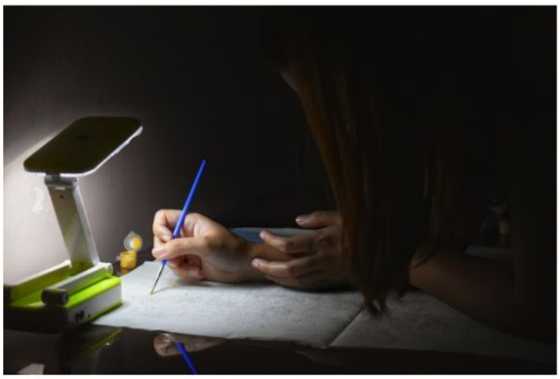
Traditional OSHA Format

The Impact of Lighting Levels on Health and Safety

Incorrect Perception and Failure to See Clearly
Low levels of lighting can affect visual perception, as demonstrated by the following incident:

"While on evening patrol, officers discovered two men lurking near a closed gas station in a high-crime area. In the confrontation that followed, the officers fired on the suspects, one of whom appeared to be holding a shotgun. The officers believed that the other man had pulled a chrome-plated handgun from his waistband. Later investigation revealed that the man was, in fact, holding a beer can. He sued the officer who shot him. During the trial, expert testimony centred on the nature of human vision, the low level of light at the time of the incident, and the results of a research study that demonstrated the ability of healthy subjects to identify lethal versus non-lethal items under a range of low levels of light."

Some work activities require the ability to see fine detail (such as work on small electronic circuit boards, sewing, and stitching activities). This will require high (and local) levels of illuminance for the task to be carried out correctly.



Stroboscopic Effects
The *stroboscopic effect* in a *fluorescent* lamp is a phenomenon which causes running or moving equipment to appear stationary or appear to be operating slower than they actually are.

In an AC supply, the voltage drops 100 times a second to zero volts as the supply frequency is 50 Hz. When a fluorescent lamp is operating with an AC supply, the light intensity drops 100 times a second. This flicker is not noticeable to the human eye due to the persistence of vision.

When a worker in a factory observes a running machine (for example, a flywheel) under the illumination of a fluorescent light, the flywheel may appear to be stationary or to be operating at reduced speed. This can result in accidents and is highly dangerous.

When using fluorescent lamps around rotating or moving machinery, two lamps powered by two different phases should be used. This ensures that the lamps flicker at different speeds, ensuring a continuity of vision. If another phase is not available, a capacitor can be added in series to one lamp. This ensures that there is a phase lag between the two lamps.

Colour Assessment
All types of light have a particular colour. Ideally, light should be white since this does not affect our perception of other colours.

However, some lighting makes objects and surfaces appear to be a different colour e.g. a blue object looks black, or a yellow wire looks green.

Sodium lighting is known for changing our perception of colour.

Incorrect perception of colour by an individual can be a contributory factor in incidents involving, for instance, electricity supply (e.g. incorrect wiring of an electrical fitting).

Lighting effect on attitudes
The "Hawthorne effect" arose because of a series of experiments conducted between 1924-32, at the Hawthorne Works in Chicago. They had commissioned a study to see if their workers would become more productive in higher or lower levels of light. The workers' productivity seemed to improve when changes were made and slumped when the study ended. It was later suggested that the productivity gain occurred because of the motivational effect on the workers of the interest being shown in them.

Despite the fact that the Hawthorne study failed to account for other factors, thereby muddying the results of their research on lighting in the workplace, it cannot be denied that providing a well-lit atmosphere for employees has the potential to boost productivity. Here are just a few ways in which poor lighting could be the culprit behind a workforce that simply is not working as efficiently as they could.

For starters, there are all kinds of lighting, from the natural end of the spectrum to incandescent bulbs to glaring fluorescent overheads. Each may have a dramatically different effect on workers. And when you throw in the competition from a computer monitor (common to nearly every workplace these days) the type and amount of lighting could cause issues with productivity.

Lighting can affect us on both a physical and mental level when it comes to our motivation and ability to complete work.

Effects on health
Poor lighting makes the visual system work harder and may lead to symptoms commonly described as eyestrain.

Symptoms of eyestrain vary according to the lighting conditions and the task being carried out. They can disappear after taking adequate rest or breaks away from a particular activity.

Symptoms include:

- Irritation, such as inflammation of the eyes and lids
- Itchiness
- Breakdown of vision blurred or double vision
- Referred symptoms, such as headaches, fatigue, giddiness

Poor lighting can also cause other, more indirect effects. The natural response to insufficient illuminance, for example, is to get closer to the task or to look at it from a different direction. This can mean adopting unsuitable postures that lead to other forms of discomfort such as neck and backache.

Why different work areas will need different light conditions
At its simplest, different levels of lighting are required for different types of work – close, accurate work such as soldering a control panel will require higher light levels than walking down a corridor. However, when considering lighting, a number of different things need to be considered, including colour, contrast, and glare.

10.2: Confined Spaces

The meaning of confined spaces

In the UK legislation Confined Spaces Regulations 1997, a confined space is defined as:

"any place, including any chamber, tank, vat, silo, pit, trench, pipe, sewer, flue, well or other similar space in which, by virtue of its enclosed nature, there arises a foreseeable specified risk"

The definition of "specified risk" is given as:

"a risk of:

- Serious injury to any person at work form fire or explosion.
- The loss of consciousness of any person at work arising from an increase in body temperature.
- The loss of consciousness or asphyxiation of any person at work arising from gas, fume, vapour, or the lack of oxygen.
- The drowning of any person at work arising from the increase of the level of liquid: or
- The asphyxiation of any person at work arising from a free flowing solid or the inability to reach a respirable environment due to entrapment by a free flowing solid"

A confined space must have **both** of the following features:

- **Substantially enclosed** (but not always entirely).
- One or more of the **specified risks** must be **present** and **reasonably foreseeable**.

It is easy to identify some confined spaces e.g. sewers, closed tanks that store chemicals or compressed gas. Some are not obviously confined spaces for example:

- Grain stores, silos which are large areas and fairly easy to work in.
- Rooms or loft spaces which have various entrances or exits and seem easy to escape from.
- Regular workplaces which include offices, changing rooms, bathrooms, kitchens, spray booths.

Temporary/intermittent Confined Spaces
If an area is not usually a confined space, a change in circumstances or the amount of enclosure can mean that it becomes classed as a confined space. This can be a permanent change, or it could be intermittent. For the most part, the area would be free of contaminants and have a safe level of oxygen. It could be affected by:

- Welding - which would consume oxygen and produce heat.
- Paint spraying introducing solvents/fumes into a spray booth.
- Cleaning where the chemicals used could add contaminants of react with residues to create a toxic atmosphere.

In these cases, the space would only be classed as a confined space whilst work is being undertaken. Once the contaminants have been cleared, the area ventilated, or a reasonable temperature restored the area is no longer considered a confined space. In other words, the area would cease to be a confined space once the "specified risk" is removed.

The risks of a confined space can also change depending on the circumstances such as heavy rain in an excavation which introduces the risk of drowning.

Other examples of confined spaces include:

- Ducts, tunnels, manholes, shafts, tanks, excavations, trenches, garage inspection pits.
- Freight containers, ship's cargo holds, ballast tanks.
- Some enclosed rooms (particularly plant rooms.
- Enclosures for the purpose of asbestos removal.
- Unventilated or inadequately ventilated rooms and silos.
- Structures that become confined spaces during fabrication.
- Machine interiors.

Factors to be Considered when Assessing Risk

The first thing to consider, and a requirement of the regulations, is can we avoid the need to enter the confined space? For example, can we clean a vessel from the outside or by inserting automatic pressure jetting cleaning into the vessel; can we clear a blockage on a grain silo by fitting an external vibrating device? can we inspect the interior of a large pipeline by inserting an intelligent PIG (pipeline intelligent gauge fitted with camera).

If entry cannot be avoided, then the risk assessment needs to consider:

The Confined Space Itself

Previous contents
Information about any substances previously held in the confined space will give an indication of what kind of hazard may be expected, for example toxic or flammable gases.

Residues
Danger may arise because of residual chemical, scale, rust, sludge, or other residues in a confined space. For example, dangerous gas, fume, or vapour. For example, residual sludge in a crude oil tank may release hydrogen sulphide or flammable vapours when disturbed.

Contamination
Contamination may arise from adjacent plant, processes, gas mains or surrounding land, soil or strata. Gases and liquids may leak, or may have leaked, into the confined space from adjacent plant, installations, processes, or landfill sites. This is a risk where confined spaces are below ground because they can be contaminated by substances from installations many metres away.

The Abbeystead disaster in 1984 occurred when methane gas from coal seams below seeped into an enclosed pumping station. The resultant explosion resulted in the deaths of 16 people
In certain situations, water in ground or gases may enter the confined space from the surrounding land, soil, or strata. For example, acid groundwater acting on limestone can lead to dangerous accumulations of carbon dioxide in, for example, excavations or sewers.

Oxygen deficiency and oxygen enrichment
There are significant risks because of an oxygen enriched atmosphere (i.e. greater than 20.9%). Oxygen enrichment will increase flammability of clothing and other combustible materials, as occurred on HMS Glasgow when a fire and explosion in an oxygen enriched atmosphere killed eight men at Swan Hunter's Neptune yard at Walker, Newcastle, on September 23, 1976.).

Conversely, a relatively small reduction in the oxygen percentage can lead to impaired mental ability. The effects occur rapidly, even in circumstances where only a person's head is inside a confined space. Very low oxygen concentrations (i.e. below 16%) can lead to unconsciousness and death.

Physical dimensions
The possible effects of the dimensions and layout of the confined space need to be considered. Air quality can differ if the space contains remote or low-lying compartments. Isolated pockets or regions within the space need to be considered when choosing ventilation methods.

The Task being Undertaken

The task itself may produce the hazard. Alternatively, work being done on the exterior or outside of the confined space (e.g. external welding; chemical cleaning of nearby drains) could also create hazardous conditions within. Hazards that can be introduced into a space that may otherwise be safe include:

Cleaning chemicals
Chemicals used for cleaning could affect the atmosphere directly or interact with residual substances present in the confined space.

Sources of ignition
Welding could act as a source of ignition for flammable gases, vapours (e.g. from residual sludges), dusts, plastics and many other materials which may burn leading to a fire or explosion. Welding on the outside of a confined space can easily ignite materials in contact with the metal on the inside (there have been many cases of explosions where people have used a burning torch to cut up a flammable liquid free drum and forgot about residual vapours). Specially protected tools, equipment, or lighting may need to be used in potentially flammable or explosive atmospheres so that they do not present a source of ignition.

Increasing temperature
Work in a confined space will generally, naturally increase the body temperature. The situation is worsened if activities such as welding work is being carried out. Any strenuous work activity can also influence thermal comfort of workers, where PPE must be worn.

External Hazards

The confined space will need to be isolated to prevent dangers arising from outside. For example:

Ingress of substances
Any pipe work connected to a vessel, for example, will need to be positively isolated to prevent substances from other parts of the process from re-entering the vessel while work is being carried out in the vessel.

There may also be a risk of carbon monoxide, carbon dioxide and nitrogen dioxide present in the exhaust of combustion engines entering the confined space. (for example, a mobile compressor that is being used as part of an excavation activity).

Persons at Risk

The risk assessment should identify the risks to those entering/working in the confined space, and to anyone else in the vicinity who may be affected by the activity, for example other employees, contractors, or members of the public.

Emergency Rescue

The Regulations require an emergency plan to be in place before work takes place in a confined space. Possible

emergencies should be anticipated, and appropriate rescue arrangements made. This includes equipment that may be needed for rescue purposes (such as a tripod).

Factors to be Considered when Designing Safe Practices

The risk assessment process should lead on to the designing of a safe system of work (SSOW) for safe entry and work in a confined space.

Consideration should be given to:

- The level of supervision, including the possible need to appoint a competent person to supervise the work.
- Suitability and competence of the workers, including experience, training, physical health and mental attributes (specific training, for example, may be required for the person allocated "stand-by" duties; for the supervisor in charge of the work; for the emergency rescue team).
- The need for adequate communication arrangements to summon help in an emergency, or to allow those inside the space to communicate both with each other and those outside (any person who has been allocated "stand by" duties).
- Ventilation of the confined space, whether natural or forced ventilation will be required.
- Whether cleaning the space or removal of residues is necessary and how this is to be done.
- Testing of the atmosphere within the space, including the choice of test equipment, the type of contaminates and level of oxygen.
- Whether gases, liquids, free-flowing solids, and mechanical and electrical equipment need to be isolated and the way that this is to be achieved.
- Access and egress - the provision of, wherever possible, unobstructed access/egress to allow quick escape in the event of an emergency.
- Selection and use of suitable equipment for working or rescue within the space, including lighting and Personal or Respiratory Protective Equipment. In cases where heat or humidity levels are high and PPE or RPE is being worn, it may be required to limit working time.
- Whether machinery fuelled by petrol, diesel or gas can be excluded from the space.
- Prevention of static electricity build-up including earthing and bonding, and control procedures for hoses and pipelines (for example, if carrying out pressure jetting or shot blasting activities in the confined space).
- Arrangements for access, egress, emergency situations and emergency rescue.

- Materials storage, fire prevention including smoking control arrangements inside and outside the space. Smoking should not be permitted in confined spaces; the results of a risk assessment will determine whether it is necessary to extend this rule beyond the confined space.
- The provision of signage to warn against unauthorised entry.

The Safe System of Work developed for confined space entry and work therein should make provision for the use of a Confined Space Permit to Work - the controlling document for such activities.

10.3: Flammable and explosive materials and the mechanisms by which they ignite

The relevant properties of solids, liquids, and gases with respect to influence on combustion

Solids
For solid fuels to burn the substance needs to melt and vaporise (for example, thermoplastics), or be pyrolysed (decomposed) into gases or vapours (for example, wood). In both cases, heat is required for the fuel to generate the vapours.

Materials which are high density (such as woods, plastics) conduct energy away from the area of the ignition source more rapidly than low-density materials, which act as insulators allowing the energy to remain at the surface. For example, oak takes longer to ignite than a soft pine (given the same ignition source). On the other hand, low-density foam plastic ignites more quickly than high- density plastic.

The surface area (to mass ratio) also affects the amount of energy necessary for ignition. For example, it is relatively easy to ignite one kilogram of thin pine shavings with a match, whilst ignition of a one-kilogram solid block of wood with the same match is very unlikely.

Liquids
A liquid must be at, or above, its flash point to generate vapours to form an ignitable mixture.

Atomized liquids or mists (those having a high surface area to mass ratio) can be more easily ignited than the same liquid in the bulk form.

Gases
Combustible substances in the gaseous state have extremely low mass and require the least amount of energy for ignition.

The meaning of Fire and Explosion related terms

Flash Point
Is defined as the lowest temperature at which a liquid will give off sufficient vapour to ignite momentarily on the application of a flame.

Liquids with low flash points pose the greatest danger (for example: Gasoline/Petrol has a flashpoint of -40°C).

Fire point
The fire point of a fuel/substance is the lowest temperature at which the vapour of that fuel/substance will continue to burn for at least 5 seconds after ignition by an open flame.

Auto-ignition temperature
The auto-ignition temperature of a fuel/substance is the lowest temperature at which the vapour of that fuel/substance spontaneously ignites in normal atmosphere without an external source of ignition. (such as a spark or flame.).

Substances like boranes, silanes, and white phosphorous all have notoriously low auto-ignition temperatures. Gasoline has a relatively high auto-ignition temperature.

Vapour density
Is the density of a vapour, or gas, in relation to hydrogen (or, in the USA, air).

Vapour density has implications during storage and personnel safety - if a container can release a dense gas, its vapour could sink and, if flammable, collect until it is at a concentration sufficient for ignition.

Flammable limits

Upper flammable limit (UFL)
Is the highest concentration of vapour in air/oxygen that is still flammable (above the UFL the mixture is too rich to ignite).

Lower flammable limit (LFL)
Is the lowest concentration of vapour in air/oxygen that is still flammable (below the LFL, the mixture is too lean to ignite).

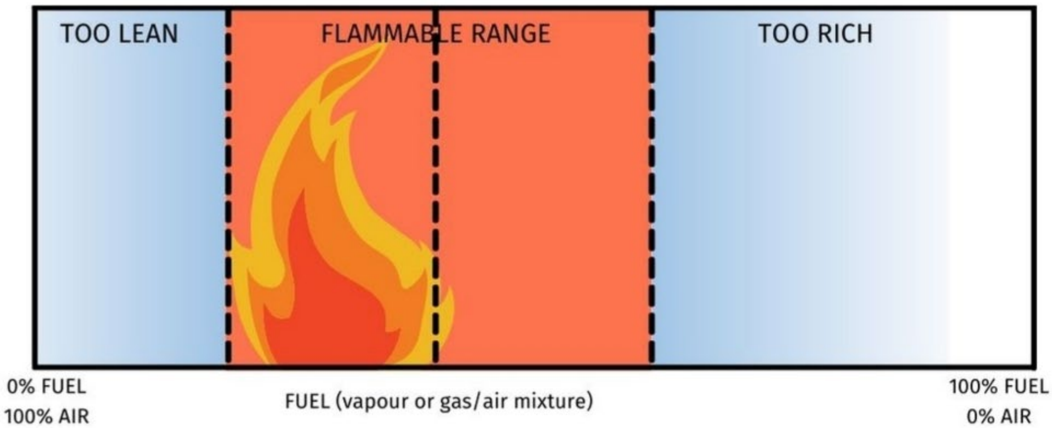
(These are also commonly referred to as the upper and lower "*explosive limits*").

Different substances have different flammable limits (often referred to as the "*flammable range*").

Examples include:

- **Methane**: Flammable range: 5 - 15%
- **Propane**: Flammable range: 2 - 10%
- **Hydrogen**: Flammable range: 4 - 75%

The *flammable* range is therefore the concentration **range** of a gas or vapour that will burn (or explode) if an ignition source is introduced.



Vapour cloud explosions

There are a number of ways that vapour clouds can be generated, including:

- Sudden depressurisation, or rupture, of a pressurised vessel (for example: LPG).
- The overfilling of a storage tank (for example: Buncefield 2005).
- A hydrocarbon spillage and subsequent evaporation (for example: LNG).
- As a result of a poorly controlled draining operation.
- Uncontrolled build-up of vapour within a vessel.

When the hydrocarbon vapour is mixed with air, and the mixture is within the flammable limits, all that is required is a source of ignition to generate a *vapour cloud explosion*. The explosion can be either a *detonation* or a *deflagration*.

Unconfined Vapour Cloud Explosion (UVCE)

An unconfined vapour cloud arises from the sudden, or significant, release of flammable gas/vapour into the atmosphere. A UVCE occurs when this cloud mixes with air (within the flammable limits) and finds a source of ignition.

High overpressures can be generated from this type of explosion. This is possible when the vapour cloud is ignited in the vicinity of plant structures with two key geometrical features - a dense distribution of obstacles in the path of the flame front, and a configuration of parallel planes (such as boundary walls), which provides confinement for the explosion.

Such explosions have the potential for considerable widespread destruction (for example: Buncefield 2005; Texas City 2005; Flixborough 1974).

https://www.hse.gov.uk/comah/buncefield/index.htm

The Flixborough Unconfined Vapour Cloud Explosion

Accident summary

At about 16:53 hours on Saturday 1st June 1974, the Nypro (UK) site at Flixborough was severely damaged by a large explosion. Twenty-eight workers were killed, and a further 36 suffered injuries. It is recognised that the number of casualties would have been far higher if the incident had occurred on a weekday, as the main office block was not occupied. There were fifty-three reported injuries off-site. Property in the surrounding area was damaged to a varying degree.

Prior to the explosion, on 27th March 1974, it was discovered that a vertical crack in reactor No.5 was leaking cyclohexane. The plant was subsequently shut down for an investigation. This identified a serious problem with the reactor, and the decision was taken to remove it and install a bypass assembly to connect reactors No.4 and No.6 so that the plant could continue production.

During the late afternoon on 1st June 1974, a 20-inch bypass system ruptured, which may have been caused by a fire on a nearby 8-inch pipe. This resulted in the escape of a large quantity of cyclohexane.

The cyclohexane formed a flammable mixture and subsequently found a source of ignition. At about

16:53 hours, there was a massive vapour cloud explosion which caused extensive damage and started numerous fires on the site.

Eighteen fatalities occurred in the control room as a result of the windows shattering and the collapse of the roof. No-one escaped from the control room. The fires burned for several days and after ten days, those that still raged were hampering the rescue work.

Failings in Technical Measures included:

- A plant modification occurred without a full assessment of the potential consequences.
- Only limited calculations were undertaken on the integrity of the bypass line.
- No calculations were undertaken for the dog-legged shaped line or for the bellows.
- No drawing of the proposed modification was produced.
- Plant Modification/Change Procedures: HAZOP.
- Design Codes - Pipework: use of flexible pipes.
- No pressure testing was carried out on the installed pipework modification.
- Those concerned with the design, construction and layout of the plant did not consider the potential for a major disaster happening instantaneously.
- Plant Layout: positioning of occupied buildings.
- Control Room Design: structural design to withstand major hazards events.
- The incident happened during start-up when critical decisions were made under operational stress.

Confined Vapour Cloud Explosion (CVCE)

Occurs as a result as the ignition of a flammable vapour (when mixed with air) which is under confinement (such as in a building or a vessel). Only small amounts of flammable vapour are necessary (for example: flammable material left in a drum). The explosion and pressure generated may be sufficient to rupture the containment and cause considerable localised damage.

Boiling Liquid Expanding Vapour Cloud Explosions (BLEVE)
A BLEVE occurs when a vessel containing a pressurised liquid and vapour (such as propane or butane) catastrophically fails, usually because of an external fire affecting the vessel's walls.

The heat is initially absorbed by the liquid but causes the pressure within the vessel to increase. This causes the relief valve to open, which allows the pressurised vapour to escape. As the liquid level in the vessel decreases, the flames impinge on the vessel wall above the liquid level. This part of the wall rapidly heats up because it is not protected by the cold liquid inside the tank. The wall weakens and then tears, resulting in a sudden catastrophic failure of the vessel.

This causes a rapid boiling of the liquid because of the pressure drop, which then releases large amounts of vapour. On mixing with the air, and finding contact with an ignition source, the vapour cloud will explode violently, generating a significant fireball, and causing large fragments of the vessel to be projected significant distances. In addition, other major consequences include massive thermal radiation and blast waves. The debris and thermal radiation can cause a chain reaction if other storage tanks are nearby.

Examples of major BLEVE incidents include Mexico City 1984 and Feyzin 1966.

PEMEX LPG Terminal, Mexico City, Mexico. 19th November 1984

Summary
At approximately 05:35 hours on 19th November 1984, a major fire and a series of catastrophic explosions occurred at the government-owned and operated PEMEX LPG Terminal at San Juan Ixhuatepec, Mexico City. As a consequence of these events, some 500 individuals were killed, and the terminal destroyed.

Three refineries supplied the facility with LPG on a daily basis. The plant was being filled from a refinery 400 km away, as on the previous day it had become almost empty. Two large spheres and 48 cylindrical vessels were filled to 90%, and 4 smaller spheres to 50% full.

A drop in pressure was noticed in the control room and also at a pipeline pumping station. An 8-inch pipe between a sphere and a series of cylinders had ruptured. Unfortunately, the operators could not identify the cause of the pressure drop. The release of LPG had been going on for about 5-10 minutes when the gas cloud, estimated at 200m x 150m x 2m high, drifted to a flare stack. It ignited, causing violent ground shock. A number of ground fires occurred. Workers on the plant now tried to deal with the escape, taking various actions. At a late stage, somebody pressed the emergency shut-down button.

About fifteen minutes after the initial release, the first BLEVE occurred. For the next hour and a half, there followed a series of BLEVEs as the LPG vessels violently exploded. LPG was said to rain down and surfaces covered in the liquid were set alight. The explosions were recorded on a seismograph at the University of Mexico.

Failings in Technical Measures
The total destruction of the terminal occurred because there was a failure of the overall basis of safety, which included the layout of the plant and emergency isolation features.

Specific issues included:

- Plant Layout: positioning of the vessels.
- Isolation: emergency isolation means.

- The terminal's fire water system was disabled in the initial blast. Also, the water spray systems were inadequate.
- Active/Passive Fire Protection: survivability of critical systems, insulation thickness, water deluge.
- The installation of a more effective gas detection and emergency isolation system could have averted the incident. The plant had no gas detection system and therefore, when the emergency isolation was initiated, it was probably too late.
- Hindering the arrival of the emergency services was the traffic chaos, which built up as local residents sought to escape the area.
- Emergency Response/Spill Control: site emergency plan, access of emergency vehicles.

The Prevention and Mitigation of Vapour Phase Explosions

The prevention of vapour cloud explosions should start at the *design* stage. This involves a thorough analysis and risk assessment of all scenarios that could lead to vapour phase explosions.

Designing out the hazard is the best option - for example, can the risk be eliminated by using a non (or less) dangerous substance or by using an alternative, safer process.

Plant and equipment used to handle, store, or produce dangerous substances should be designed to an appropriate domestic national or international standard (where available) to avoid or minimise any unintended release of dangerous substances.

For example:

- Plant layout: the considered layout of plant and equipment can mitigate the effects of a fire and explosion. This might be by distance or by fire resistant barriers (for example, explosion resistant walls).
- Ensuring that the plant is corrosion and abrasion resistant, manufactured from compatible material or treated to impart resistance.
- Having effective process control systems to ensure that the process is kept within its safe operating limits and alarm systems to warn when those limits are being exceeded (for example, high level alarms on storage tanks; overpressure alarms on reaction vessels).
- Ensuring that piping and equipment inspections and preventive maintenance tasks are completed as required to ensure the mechanical integrity of process equipment.
- Ensuring that employees are properly trained, and safe systems of work/safe operating procedures are in place in order to further reduce the risk of human error.
- Loading or unloading operations and facilities are designed, located, and operated to minimise the risk of leaks, spills, overfilling and the inadvertent mixing of incompatible materials.

Other techniques will include ensuring that *ignition* sources are absent from areas where flammable vapours may be present, for example, *hazardous* area classification and zoning to ensure the suitability of electrical equipment in the area and segregation of incompatible and dangerous substances.

Mitigation measures *structural protection*, or barriers, to minimise the effects of an explosion; *explosion relief systems* (such as blow out panels; relief valves and bursting discs); explosion *suppression systems*.

Mechanisms of explosions and fire-spread

How an Explosion/Fire Occurs

Fire

Fire occurs because of the rapid oxidation of combustible material, which releases heat, light and various chemical products (such as carbon monoxide and carbon dioxide.) The fire triangle describes the conditions that must be met in order for a fire to start, that is the presence of combustible material, oxygen, and energy to ignite the fire.

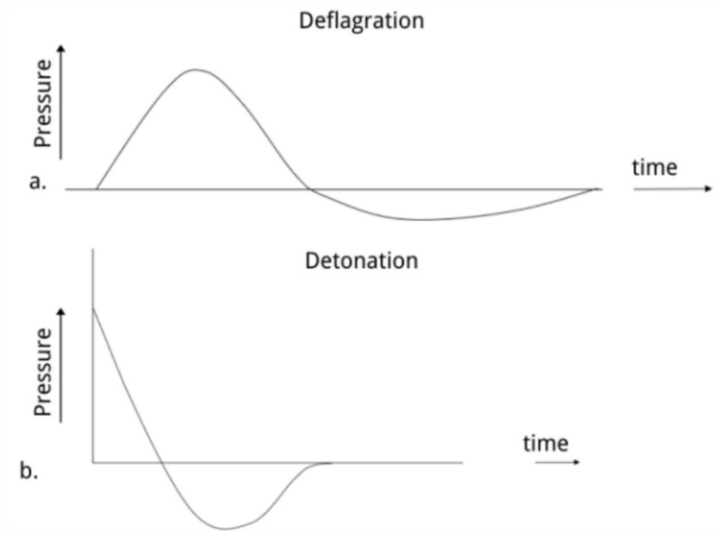
Explosion

An explosion is a rapid increase in volume and release of energy in an extreme manner, usually with the generation of high temperatures and the release of gases. An explosion creates a blast wave. Explosion may be *Detonations* or *Deflagrations*.

A *detonation* is a dramatic, often destructive form of an explosion. It is characterised by a supersonic exothermic front (more than 100 m/s up to 2000 m/s) and significant overpressure (up to 20 bars). The front drives a pressure wave ahead of it. Explosives such as Dynamite; TNT and Nitro-glycerine produce detonations.

If the blast wave is sub-sonic, it is termed a "*Deflagration*." Everyday fires and most explosions are deflagrations. (For example, internal combustion engines; lighting a gas stove).

The overpressure characteristics of deflagrations and detonations as a function of time are very different. *Deflagrations* are usually characterised by a gradual increase to peak overpressure over time, followed by a gradual decrease in overpressure. This wave form is generally referred to as a pressure wave. Detonations are characterised by a rapid rise to peak overpressure followed by a steady decrease of overpressure to form the so called "shock front."



The Combustion Process

Combustion may be defined as:

"the rapid chemical combination of a substance with oxygen, involving the production of heat and light."

Complete combustion releases more energy than incomplete combustion. Incomplete combustion also creates carbon monoxide, and more soot.

Complete combustion
Complete combustion needs a plentiful supply of air so that the elements in the fuel react fully with oxygen. Fuels such as natural gas and petrol contain hydrocarbons. These are compounds of hydrogen and carbon only when they burn completely.

Incomplete combustion
Incomplete combustion occurs when the supply of air or oxygen is poor. Water is still produced, but carbon monoxide and carbon are produced instead of carbon dioxide.

In general, for incomplete combustion:

- Hydrocarbon + oxygen -> carbon monoxide + carbon (as soot) + water

Exothermic and Endothermic Reactions

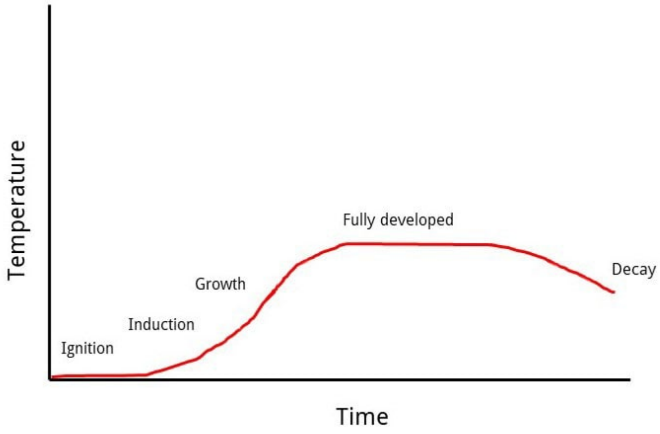
Exothermic reactions transfer energy to the surroundings. The energy is usually transferred as heat energy, causing the reaction mixture and its surroundings to become hotter. Examples include burning and neutralisation reactions between acids and alkalis.

Endothermic reactions take in energy from the surroundings. The energy is usually transferred as heat energy, causing the reaction mixture and its surroundings to get colder. Examples include electrolysis and the reaction between ethanoic acid and sodium carbonate.

The Stages of Combustion

There are five basic stages of the combustion process.

These are illustrated in the diagram that follows.



Induction
Sufficient vapour is generated when heat is applied to a fuel, which mixes with air and generates a flammable mixture. Often termed "smouldering", this can be a slow process where the build up to ignition may take some time.

Ignition
The chemical reaction is initiated (the point at which visible flames may be seen) and the reaction becomes self-sustaining, and the temperature starts to rapidly increase.

Growth
With the initial flame as a heat source, the fire begins to spread (direct contact, conduction, convection, and radiation). The growth rate will depend on the type and amount of fuel and the amount of available oxygen.

Fully Developed
When the growth stage has reached its maximum and all combustible materials have been ignited, a fire is considered fully developed. This is the hottest phase of a fire.

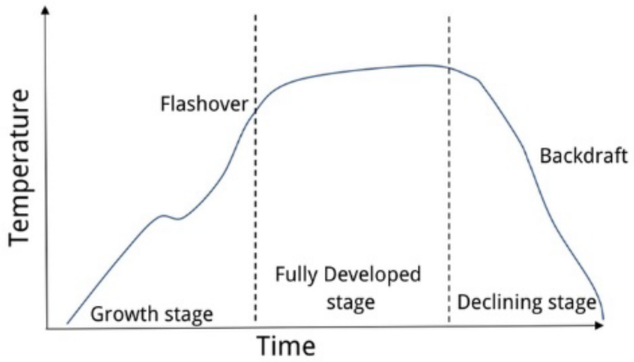
Decay
Usually the longest stage of a fire, the decay stage is characterized by a significant decrease in oxygen or fuel, putting an end to the fire. A common danger at this stage is the danger of a "back draft" - which occurs when oxygen is reintroduced to a volatile, confined space.

Two important phenomena, associated with enclosed fires (buildings) that increase the fire risk are:

Flashover
A *flashover* is defined as "the sudden involvement of a room or an area in flames from floor to ceiling caused by thermal radiation feedback." It occurs because of the energy of the fire being radiated back to the contents of the room from the walls, floor, and ceiling. This radiation of energy to the contents of the room will raise ALL the contents to their ignition temperature. When the contents of the room suddenly and simultaneously ignite, this is flashover.

Backdraft
A *backdraft* is a smoke explosion that can occur when additional air is introduced into a smouldering fire and heated

gases enter their flammable range and ignite with explosive force. A backdraft is an "air-driven event," unlike a flashover, which is temperature driven.



The effects of atomisation/particle size and oxygen content on the likelihood and severity of fire/explosion

The particle size of a given combustible dust has a significant influence on its ability to explode. In general, a decrease in particle size has been shown to increase the likelihood of occurrence of a dust explosion as well as its severity.

Minimum Explosive Concentration (MEC), Minimum Ignition Energy (MIE) and Minimum Ignition Temperature (MIT) all decrease with decreasing particle size. This is because a smaller particle means a larger surface area and therefore greater reactivity. Finer particles (typically < 75 µm) contribute to the way dust reacts and how explosive it can become.

Oxygen is the most common oxidant found in industry.

Whilst an oxidant must be present for combustion to occur, it does not need to be completely removed to prevent the occurrence of a dust explosion. The limiting oxygen concentration (LOC) is defined as the highest oxygen concentration at which an explosion fails to occur in each dust/air/inert gas mixture (Inerting can greatly reduce the risk of a dust explosion).

With regards to atomisation of fuels, UK HSL (Health and Safety Laboratory) research has shown that, whilst minimum ignition energy is generally higher for mists than vapours (although mists composed of smaller droplets require less energy to ignite than those composed of larger droplets, since they have a higher surface area) the LFL of a mist can fall to as low as 10% of the LFL of the vapour. This reduction in the LFL is related to the size of the droplets in the mist, with the lowest LFL being produced by the largest droplets.

How failure of control measures coupled with the physico-chemical properties of flammable materials can bring about an explosion

Ultimately the hazard is created by the physico-chemical and chemical properties of a flammable material and the way it is used or presented.

Examples of relevant physical properties include:

- Boiling point, flashpoint, auto-ignition temperature
- Flammability, vapour pressure, thermal sensitivity
- Mechanical sensitivity and oxidising properties

Relevant chemical properties would include:

- Reactivity, heat of reaction
- Self-acceleration and decomposition temperature

For materials that could be dispersed in air to give rise to a risk of a dust explosion, the consequences and magnitude of this are significantly influenced by the composition and nature of the material, including its particle size.

Materials that are in liquid form pose a relatively low risk of fire or explosion until it is vaporised or atomised, mixed with oxygen/air and finds an ignition source.

As an example of a control failure, at an ARCO chemical plant in Texas in 1990, a wastewater tank exploded during the re-start of a compressor. The nitrogen purge in the tank had been greatly reduced during maintenance on the tank. This was not detected by a temporary oxygen analyser. When the compressor was restarted, flammable vapours were sucked in and ignited. The flashback of the flame into the headspace of the tank caused an explosion that killed 17 people.

The Buncefield explosions and fire in 2005 occurred when a gasoline tank was being filled as a result of a number of control failures, including the failure of both the automatic tank gauging and independent high-level switch as the level in the tank increased. This resulted in an overflow of volatile gasoline. A vapour cloud formed which ignited causing a massive explosion and a fire that lasted five days.

The Effects of Oxidising substances on Fires and Explosions

Oxidisers are substances that can decompose readily to yield oxygen. They can supply combustible substances with oxygen and support a fire even when air is not present. They can also:

- Speed up the development of a fire and make it burn more intensely
- Cause substances to burn rapidly that do not normally burn readily in air
- Cause combustible materials to burn spontaneously without the presence of an ignition source such as a spark or flame.

Chromates, chlorates, and nitrates are examples of oxidising substances.

Flammable atmospheres: How they arise and where they can be found

How they arise and where they can be found

Examples of how flammable atmospheres can be found in workplaces include:

- **Filling and unloading** - the normal process of topping up and taking off from a crude oil tank, where some vapour can always be expected to be present in the tank.

- **Dispensing and decanting** - decanting a flammable substance from a large storage vessel into smaller containers.
- **Naturally occurring** - methane may be present during mining or tunnelling work.
- **Cleaning activities** - substances that may be used for cleaning in preparation for maintenance work (solvents, for example).
- **Maintenance work** - the Swan Hunter explosion in 1976 occurred as a gas leak from welding bottles during maintenance work. Other explosions have been caused because of not properly removing flammable vapours from equipment before hot work.
- **Spillages and leaks** - spillage and evaporation of flammable liquids; leak of flammable gas (the Buncefield fire/explosions in 2005 occurred because of the overfilling of a gasoline storage tank).
- **Dusts** - combustible dusts which may be dispersed to give rise to an explosive atmosphere (e.g. wood dust).

Control measures for entering flammable atmospheres
Potentially flammable atmospheres may need to be periodically entered, or breached, for cleaning or maintenance purposes. Under the control of a permit to work, additional controls would include:

Purging of equipment that has contained flammable material before hot work is allowed to start. This can be achieved by pressurising/purging with an inert gas such as nitrogen, thereby partially or completely substituting the air or flammable atmosphere - e.g. moving it below its lower flammable limit.

Ventilating a tank or vessel before allowing entry. This can be done by natural ventilation (by opening access point manholes) or "forced" ventilation (by attaching an eductor fan to an access point and drawing fresh air through to displace any residual flammable gases).

When flammable atmospheres cannot be avoided (for example, entering a tank to remove sludge that may contain flammable materials) the safe system of work for entry should ensure that no sources of ignition are present (for example, by using flameproof lighting and non-sparking tools).

The principles of selection of electrical equipment for use in flammable atmospheres
Hazardous locations may be defined as places where fire or explosion hazards may exist due to flammable gases, flammable liquid-produced vapours, combustible liquid-produced vapours, or combustible dusts present in the air in quantities sufficient to produce explosive or ignitable mixtures.

Electrical equipment that must be installed in such classified locations should be specially designed and tested to ensure it does not initiate an explosion, due to faults, to arcing contacts or high surface temperature of equipment.

The introduction of electrical apparatus for signalling or lighting in coal mines was accompanied by electrically initiated explosions of flammable gas and dust. Technical standards were developed to identify the features of electrical apparatus that would prevent electrical initiation of explosions due to energy or thermal effects. Several physical methods of protection are used. The apparatus may be designed to prevent entry of flammable gas or dust into the interior. The apparatus may be strong enough to contain and cool any combustion gases produced internally. Or, electrical devices may be designed so that they cannot produce a spark strong enough or temperatures high enough to ignite a specified hazardous gas.

In Europe, The *ATEX* directive consists of two EU directives describing what equipment and work environment is allowed in an environment with an explosive atmosphere.

- The ATEX 95 equipment directive 94/9/EC, Equipment and protective systems intended for use in potentially explosive atmospheres.
- The ATEX 137 workplace directive 99/92/EC, Minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres.

The 94 directive is primarily about free trade, the 99 directive is about control of equipment in "use".

Under the 99 directives, Employers are required to classify areas where hazardous explosive atmospheres may occur into zones. The classification given to a particular zone, and its size and location, depends on the likelihood of an explosive atmosphere occurring and its persistence if it does.

Areas classified into zones (0, 1, 2 for gas-vapour-mist and 20, 21, 22 for dust) must be protected from effective sources of ignition. Equipment and protective systems intended to be used in zoned areas must meet the requirements of the directive. Zone 0 and 20 require Category 1 marked equipment, zone 1 and 21 require Category 2 marked equipment and zone 2 and 22 require Category 3 marked equipment.

ATEX Directive

Equipment Classifications	
Category 1	Equipment intended for high-risk areas where an explosive atmosphere is present long periods
Category 2	Equipment intended for medium-risk areas where an explosive atmosphere may occur under normal operating conditions
Category 3	Equipment intended for areas where an explosive atmosphere is only likely under abnormal circumstances

Under the ATEX directive 2014/34/EU, any product intended for use in potentially explosive atmospheres must bear the ATEX "CE" mark and be affixed under the auspices of an EC Notified Body.

In the Directive equipment is divided into groups and categories.

Group I Equipment
This equipment is Intended only for use in underground mines and, in addition, those parts of surface installations of such mines.

Group 1 equipment is divided into 2 categories, M1 and M2.

Group II Equipment
Equipment in Group II is intended for use in explosive atmospheres, other than mines or their surface installations.

- **Group II - Category 1** - Equipment in Category 1 is intended for use in areas in which explosive atmospheres caused by mixtures of air and gases, vapours, or mists or by air/dust mixtures are present continuously, for long periods or frequently.

- **Group II - Category 2** - Equipment in category 2 is intended for use in areas in which explosive atmospheres caused by gases, vapours, mists, or air/dust mixtures are likely to occur.
- **Group II, Category 3** - Equipment in Category 3 is intended for use in areas in which explosive atmospheres caused by gases, vapours, mists, or air/dust are unlikely to occur, or, if they do occur, are likely to do so infrequently and for a short period only.

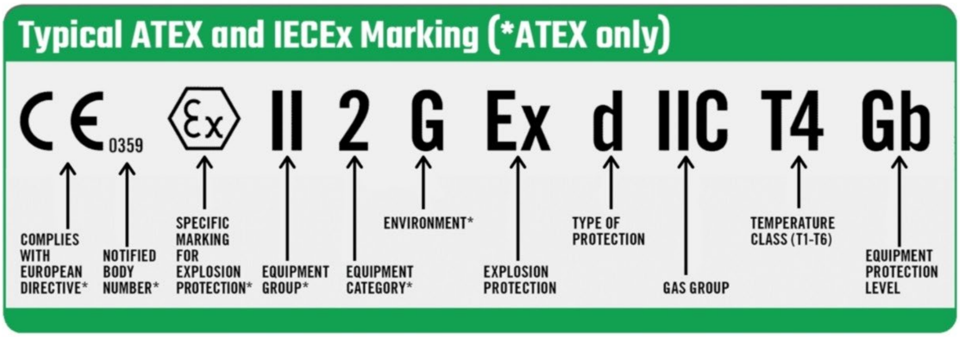
Equipment intended for use in Zone 0 would normally be classified under ATEX as Category 1. This would include equipment designed to meet the Intrinsic Safety 'ia' standard.

Equipment intended for use in Zone 1 would normally be classified as ATEX Category 2.

Equipment complying with the following protection standards are included in Category 2:

- Intrinsic safety 'ib'
- Flameproof enclosure 'd'
- Increased safety 'e'
- Purged and pressurised 'p'
- Encapsulated 'm'
- Oil filled 'o'
- Powder filled 'q.

Equipment intended for use in Zone 2 would normally be classified as ATEX Category 3. This would include equipment designed to the non-incendive 'n' standard.



The Prevention and Mitigation of Vapour Phase Explosions

The prevention of vapour cloud explosions should start at the *design* stage. This involves a thorough analysis and risk assessment of all scenarios that could lead to vapour phase explosions.

Designing out the hazard is the best option - for example, can the risk be eliminated by using a non (or less) dangerous substance or by using an alternative, safer process.

Plant and equipment used to handle, store, or produce dangerous substances should be designed to an appropriate domestic national or international standard (where available) to avoid or minimise any unintended release of dangerous substances.

For example:

- Plant layout: the considered layout of plant and equipment can mitigate the effects of a fire and explosion. This might be by distance or by fire resistant barriers (for example, explosion resistant walls).
- Ensuring that the plant is corrosion and abrasion resistant, manufactured from compatible material or treated to impart resistance.
- Having effective process control systems to ensure that the process is kept within its safe operating limits and alarm systems to warn when those limits are being exceeded (for example, high level alarms on storage tanks; overpressure alarms on reaction vessels).
- Ensuring that piping and equipment inspections and preventive maintenance tasks are completed as required to ensure the mechanical integrity of process equipment.
- Ensuring that employees are properly trained, and safe systems of work/safe operating procedures are in place in order to further reduce the risk of human error.
- Loading or unloading operations and facilities are designed, located, and operated to minimise the risk of leaks, spills, overfilling and the inadvertent mixing of incompatible materials.

Other techniques will include ensuring that *ignition* sources are absent from areas where flammable vapours may be present, for example, *hazardous* area classification and zoning to ensure the suitability of electrical equipment in the area and segregation of incompatible and dangerous substances.

Mitigation measures *structural protection*, or barriers, to minimise the effects of an explosion; *explosion relief systems* (such as blow out panels; relief valves and bursting discs); explosion *suppression systems*.

The classification of hazardous areas, zoning
Hazardous areas may be defined as "any place in which an explosive atmosphere may occur in quantities such as to require special precautions to protect the safety of workers". In this context, 'special precautions' is best taken as relating to the construction, installation and use of apparatus.

Area classification is a method of analysing and classifying the environment where explosive gas atmospheres may occur. The main purpose is to facilitate the proper selection and installation of apparatus to be used safely in that environment, considering the properties of the flammable materials that will be present.

Hazardous areas are classified into zones based on an assessment of the frequency of the occurrence and duration of an explosive gas atmosphere and are shown in the table that follows:

ZONE	Definition
ZONE 0	An area in which an explosive gas mixture is continuously present for long periods.
ZONE 1	An area in which an explosive gas mixture is likely to occur in normal operation.
ZONE 2	An area in which an explosive gas mixture is not likely to occur in normal operation, and if it does occur, is likely to do so only infrequently and will exist for a short period only.

Various sources have tried to place time limits on to these zones, but none have been officially adopted. The most common values used are Zone 0: Explosive atmosphere for more than 1000h/yr; Zone 1: Explosive atmosphere for more than 10, but less than 1000 h/yr; Zone 2: Explosive atmosphere for less than 10h/yr, but still sufficiently likely as to require controls over ignition sources.

There are different technical means (protection concepts) of building equipment to the different categories. These, the standard, and the letter giving the type of protection are shown in the following table.

Zone 0	Zone 1	Zone 2
Category 1	Category 2	Category 3
'ia' intrinsically safe EN 50020, 2002	'd' – flameproof enclosure EN 50018, 2000 (flammable atmosphere can enter but is contained within equipment)	Electrical Type 'n' EN 50021 1999 Non-electrical EN 13463-1, 2001
Ex s – Special protection if specifically certified for zone 0	'p' – Pressurised EN 50016 2002 (positive pressure inside equipment)	
	'q' – Powder-filling EN 50017, 1998 (enclosure filled within inert powder)	
	'o' – Oil immersion EN 50015, 1998 (Sparked contained by oil)	
	'e' – Increased safety EN 50019, 2000 (no components that produce sparks)	
	'ib' – Intrinsic safety EN 50020, 2002	
	'm' – Encapsulation EN 50028, 1987 (excludes flammable atmosphere)	

Similar classifications exist for dusts:

- Zone 20: An area where ignitable concentrations of combustible dust are present continuously or for long periods of time under normal operating conditions.
- Zone 21: An area where ignitable concentrations of combustible dust are likely to exist under normal operating conditions.
- Zone 22: An area where ignitable concentrations of combustible dust are not likely to exist under normal operating conditions.

Dust Explosions

Introduction

Many materials we use every day produce dusts that are flammable and in the form of a cloud can explode, if ignited.

Examples include:

- Sugar
- Coal
- Wood
- Grain
- Metals

Industries at risk therefore include the food industry; woodworking facilities; metal processing (such as zinc, magnesium, aluminium); recycling facilities (such as paper and plastics) and coal fired power plants.

Dust explosions are not new and records from over 100 years ago exist of incidents that have resulted in large loss of life and considerable and costly damage to plant and buildings.

A dust explosion at Imperial Sugar at Port Wentworth, Georgia, USA resulted in the death of 14 people.

The explosion was fuelled by massive accumulations of combustible sugar dust throughout the packaging building. The primary explosion occurred inside a sugar conveyor located beneath two sugar-storage silos that were inadequately designed and had allowed a build-up of sugar dust. That, in turn, triggered a cascade of secondary dust explosions.

The Mechanisms of dust explosions
A dust explosion involves the rapid combustion of flammable/combustible dust particles that releases energy and usually generates gaseous reaction products. A mass of solid combustible material as a heap or pile will burn relatively slowly owing to the limited surface area exposed to the oxygen of the air.

However, If the same solid in the form of a fine powder is suspended in air as a dust cloud the result will be quite different. In this case the surface area exposed to the air is much larger, and if ignition occurs, the whole of the cloud may burn very rapidly. This results in a rapid release of heat and gaseous products and in the case of a contained dust cloud will cause the pressure to rise to levels which most industrial plant is not designed to withstand.

Although a cloud of flammable/combustible dust in air may explode violently, not all mixtures will do so. The concentration of dust and air must be within the upper and lower explosive limits for the dust involved.

In addition, dust must:

- Be capable of becoming airborne and mixing with air.

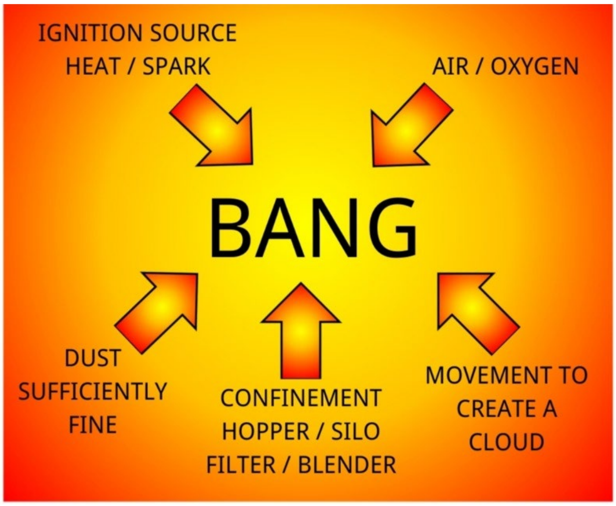
- Be of the right particle size (usually less than 200 microns).
- Have a low moisture content (usually less than 16%).
- Have enough oxygen present.
- Have an ignition source of sufficient energy present.

The most violent explosions usually result from dust/air mixtures that are fuel rich. In other words, the oxygen available in the air cannot burn all the dust, and partly burnt, glowing material often remains after the explosion. This can reignite if more air becomes available. The shape and size of the dust particles strongly affects the force of the explosion and the explosive limits.

The Dust Pentagon

For a fire to start and burn, three things are needed - fuel, ignition source, and oxygen. If any of these elements are not present, a fire cannot start. In fire safety this principle (known as the 'Fire Triangle') is commonly used to help to avoid industrial fires.

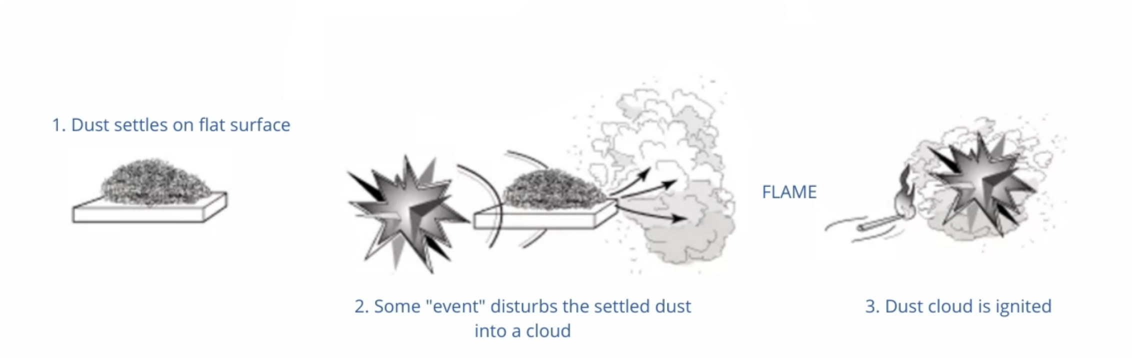
For a dust explosion to occur two more elements are required. They are *Confinement* and *Dispersion*. These elements are created when the fuel, combustible dust, is dispersed into the atmosphere as a dust cloud within a confined area, such as a room or vessel. Similar to the fire triangle, removing just one of these elements can remove the risk of a dust explosion.



Primary and Secondary dust explosions

When combustible dusts ignite, there are often two explosions known as primary and secondary explosions.

The primary dust explosion is the first explosion. It occurs when there is a dust suspension in a confined space (such as a container, room, or piece of equipment) that is ignited and explodes.



The primary explosion will shake other dust that has accumulated (for example, from dusty ledges or sills, or from damaged dust containment systems such as LEV). When this dust becomes airborne, because of the pressure wave or air turbulence created by the primary explosion, it can also ignite - with the ignition source often the primary explosion products of combustion. This is a secondary dust explosion.

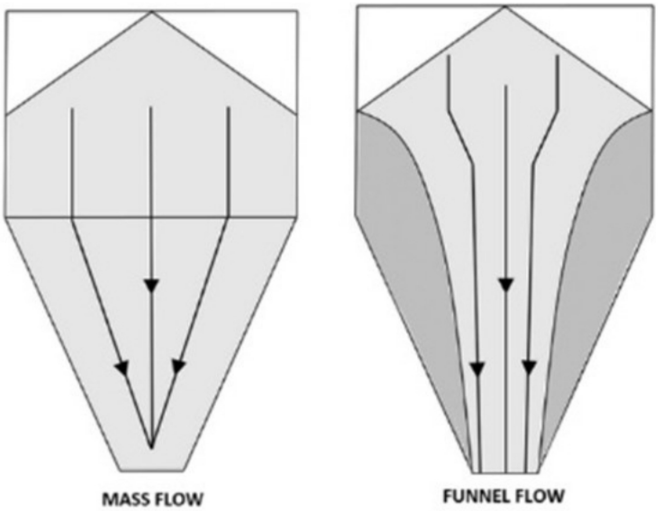
This secondary dust explosion is often more destructive than the primary one.

Prevention of Dust Explosions

Inherently Safer design

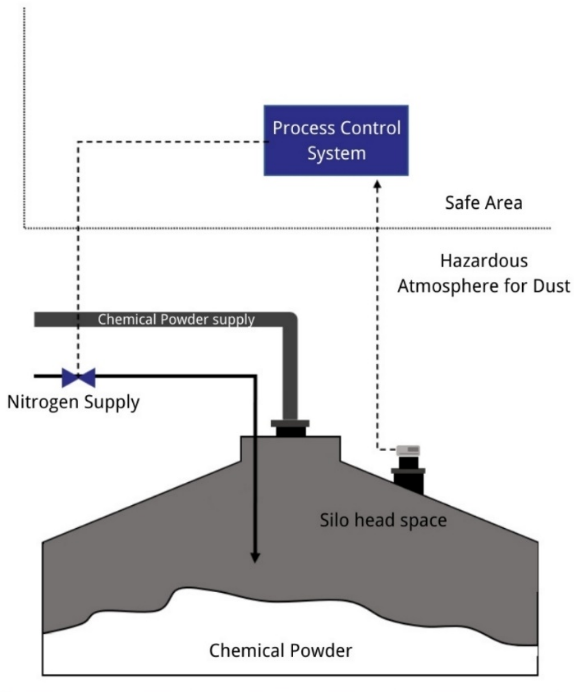
Dust explosion risks are usually combatted by applying preventive and mitigation measures to an existing process. These measures, however, can be expensive.

Inherent safety is all about ensuring that a process is designed in such a way that no explosion hazard exists. This would involve considering production, treatment, transportation, and storage operations and ensuring dust cloud generation is kept at a minimum. For example, using mass silo hoppers rather than funnel flow types.



Inerting

Explosive dust clouds can be made inert by mixing the air with an inert gas (such as nitrogen or carbon dioxide) to a level at which the dust cloud can no longer propagate a self-sustained flame. Inerting is only likely to be effective in a system that is fully enclosed, with a minimum number of places where air can enter.



A reliable supply of inert gas is required, with sufficient in reserve in order to shut the plant down safely if a seal failure or similar unexpected leak occurs (this needs to be carefully considered as in extreme cases this could lead to asphyxiation).

One man died following an explosion in a plant that manufactured powdered aluminium. Part of the process used nitrogen to maintain an inert atmosphere, but system controls were inadequate to detect blockages caused by powder collecting in the nitrogen supply pipe work.

Control of Ignition sources

Welding, burning, and cutting activities in the vicinity of dust sources must be strictly controlled. Plant should be thoroughly cleared of dust before such works commence.

Electrostatic charging of plant items or process materials is likely when moving dusty materials in quantity. It is necessary to take precautions to prevent discharges that are powerful enough to cause ignition of a dust cloud. This can be done by earthing all metalwork that may be in contact with the dust.

Like flammable liquids, gases and vapours, under the Dangerous substances in Explosive Atmosphere Regulations (DSEAR), hazardous area classification must be carried out. Dusts will be classified as Zones 20, 21 and 22. In most plant handling dusts the inside of the dust equipment will be zone 20 or 21. Rooms within the building, if they need to be zoned, will usually be the less onerous zone 22.

Again, like dangerous substances, electrical equipment for use in dusty environments should be specifically designed for that purpose. Such equipment should be marked with the sign of explosion protection (Ex), a category number (1,2, or 3) followed by the letter D for dust.

Plant Design and Controls

Examples of plant design that can control the risk of a dust explosion include:

- Large volumes of dust may escape if filters fail, relief panels become loose, or sacks being filled fall off a collection point. Monitoring of the air pressure at appropriate points within the plant can identify such an event promptly.
- Local exhaust ventilation to control the release of dust from an operation can be interlocked so that the process can only run with the ventilation operating properly.
- High-level alarms (on bins or hoppers) may be useful in preventing material being spilt.
- Deviations from a safe condition should either raise an alarm or cause, automatic plant shutdown.

Mitigation of Dust Explosions

Good Housekeeping

Dust deposits that can accumulate can provide the fuel for a secondary explosion. Dust deposits shaken into suspension from all the ledges within a room by a small primary explosion may then ignite. (note: at the design stage, "sloping" ledges should be considered in order to prevent dust build up).

The first step towards preventing dust accumulations within a building is to maintain a plant in a leak-tight condition. Loosely bolted flanged joints and damaged joints or seals are common sources of leaks. Despite this, the building will require regular cleaning, and the preferred method is a vacuum system rather than brushes and shovels, which tend to raise dust clouds.

Explosion relief venting

The provision of one or more deliberate points of weakness is a common way of protecting process plant from the consequences of an internal dust explosion. These are called explosion relief vents. If they are of suitable size and in the right place, they will safely vent an explosion within the plant.

When an explosion vent opens because of a dust explosion, a fireball or jet of flame can be expected. In addition to a mass of burning and unburnt dust there will be a pressure wave associated with the explosion. If the vent opens inside the building the burning dust may start further fires, and the blast may damage nearby plant. Anyone inside the room or building may be at serious risk. For these a duct is usually fitted to lead the explosion product to a safe place in the open air.

Image source - https://www.hse.gov.uk/research/hsl_pdf/2006/l

Explosion suppression and containment

Although explosion relief vents are the most widely used technique for protecting process plant from dust explosions, suppression and containment are suitable alternatives.

Explosion suppression systems allow a developing explosion to be controlled by the rapid injection of a suitable suppressing medium into the flame front. The suppressant is often a dry powder like those used in fire extinguishers. In certain circumstances water may be used.

Plant siting and construction

If there is a risk of explosion, despite the provision of protective measures and good control of ignition sources, the siting of unit(s) in the open air may minimise the consequences of an explosion.

A building may be vulnerable to a pressure rise from either a primary or secondary explosion (buildings with load bearing brick or stone walls have been known to collapse following dust explosions). A suitable choice of building design will allow a building to relieve a pressure wave without major damage. This can be achieved by ensuring areas such as roof or wall panels are of light construction lightly attached, or plastic glazing weakly secured to its frames.

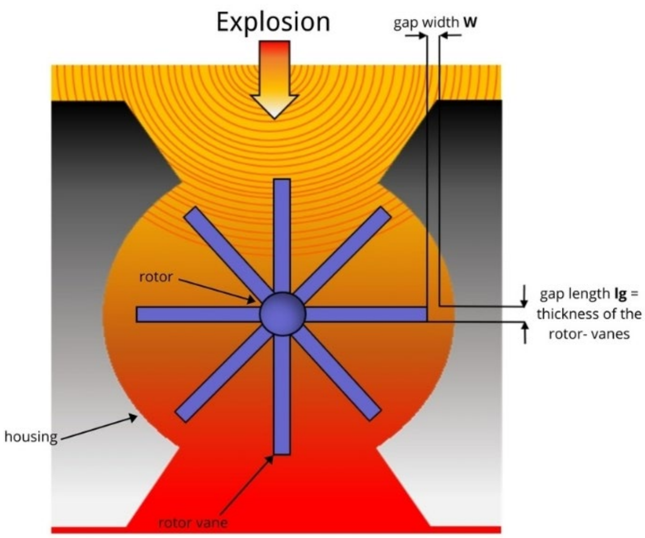
Where there is a large-scale operation (such as use of large silos) or when a large piece of plant (such as a dust filter) has a flammable dust atmosphere inside during normal operation, or when a particularly severe explosion is possible (as with certain metal dusts) serious consideration should be given to siting dust handling plant in the open air.

Interconnected plant
Where processes use a series of interconnected units (for example, grinders, elevators, cyclones, silos, and filters) unless appropriate precautions are taken, an explosion occurring in one unit can spread from one unit to another, causing extensive damage. The objective of such precautions is to prevent both the spread of burning particles, and the pressure wave associated with the initial explosion.

There are several methods that can be used to separate items of plant and so restrict this possibility, including the use of:

- Rotary valves
- Screw conveyors with a missing flight and baffle plate
- Explosion isolation valves

Rotary valves that are intended to act as explosion chokes require rigid blades (e.g. metal) that will not deform under a pressure wave, and which have as small a clearance as practicable from the casing. Both the gap width and gap length affect the ability of the valve to extinguish a flame front.



By omitting one turn of its flight, a **screw conveyor** will act as a choke to a dust explosion.

With an inclined conveyor the screw will not normally empty itself below the missing flight even when the supply of feed to the lower end stops. However, a horizontal conveyor with a trough casing needs an adjustable baffle plate to complete the seal of dust with the upper side of the casing.

Explosion isolation valves act by closing in milliseconds, following detection of a flame or pressure rise by a sensor situated an appropriate distance towards the anticipated source of the explosion. They have advantages where you want to avoid a hold up of material within the plant.

The method chosen will depend on the plant or process involved. However, on any substantial system of interconnected plant that is vulnerable to dust explosions some effective steps will need to be taken to prevent propagation of any explosion to other items of plant.

The behaviour of structural materials, buildings and building contents in a fire

The behaviour of building structures and materials in fire

The kind of materials used in construction and the way they respond to fire, clearly has a great bearing on how a structure will respond to fire. It is therefore important to develop an understanding of the behaviour of structural materials subjected to fire in terms of both the heat transfer characteristics of the material and its mechanical response to heating. The following outlines the behaviour in fire of the most important materials of construction in simple terms.

The way a material responds to fire can be classified under the following groups according to behaviour or properties:

Chemical: Decomposition, charring.

Physical: Variation in density (r), softening, melting, spalling (fragmenting or flaking).

Mechanical: Strength as measured by yield or peak stress (fy for steel and fcu for concrete).

Stiffness: as measured by the modulus of elasticity (E), creep, thermal expansion as measured by the coefficient of thermal expansion (a).

Thermal: Thermal conductivity (k), specific heat (c).

Chemical changes such as decomposition and charring are specific to wood. Physical effects such as spalling happen in concrete and masonry. Steels soften and creep but are unlikely to melt at the maximum temperatures experienced in normal fires. The table that follows shows the properties that are of interest for common structural materials:

Property	Concrete	Steel	Masonry	Wood	Plastics	Gypsum	Glass
Chemical							
Decomposition	x	x		x	x		
Charring				x	x		
Physical							
Density	x	x	x	x	x	x	x
Softening					x		x
Melting					x		x
Spalling	x		x				
Mechanical							
Strength	x	x	x	x	x	x	x
Stiffness	x	x	x	x	x	x	x
Creep	x	x	x	x	x		x
Thermal expansion	x	x	x		x	x	
Thermal							
Thermal Conductivity	x	x	x	x	x	x	x
Specific heat	x	x	x	x	x	x	x

Thermal conductivity determines the rate of heat transfer in the materials. Specific heat determines the heat absorption capacity of a material for a given rise in temperature. Most materials expand on heating (with a few notable exceptions, such as wood), and in many cases (especially in large structures with stiff restraints to expansion) this phenomenon can dominate the structural response.

Steel

Steel is arguably the most important structural material in modern construction. Steel is used in construction as structural steel or as reinforcing steel for reinforced concrete. Structural steel is considered considerably more vulnerable to fire than reinforcing steels which are encased in concrete which has good insulating properties and so protects reinforcing steels from significant losses in strength. Steels are very good conductors and tend to be used in thin sections. They are, therefore, liable to heat up very quickly in fires if not insulated. Due to these reasons most main structural steel members are required to be insulated in current design codes.

Steel reinforcement in reinforced concrete loses strength at high temperatures more rapidly than structural steel, however given adequate concrete cover, it rarely reaches high enough temperatures and in general is expected to retain its properties in a fire.

Concrete

Concrete has excellent fire resistance properties and maintains its integrity and strength in very high temperatures.

The thermal properties of concrete depend upon the aggregate type used, due to chemical changes (crystal structure) in aggregate compounds. Three common types are Siliceous aggregates (gravel, granite, flint), calcareous aggregates (limestone) and lightweight aggregates made from sintered fuel ash (Lytag) and expanded clay. Siliceous aggregate concretes tend to spall due to high thermal conductivity of such aggregate. Calcareous aggregate concretes are relatively more stable. Lightweight concrete has the best thermal properties of all, (i.e. less than half the thermal) of normal weight concrete and consequently loses its strength at a considerably lower rate.

One of the most destructive effects of fire on concrete is spalling which ranges from superficial surface damage to explosive blowout of large chunks of material. In severe fires these volume changes may be rapid enough to cause

excessive internal stresses and cause the surface layers to spall, thus exposing the reinforcement, which can lead to loss of load-bearing capacity.





Wood

Wood (or timber) is a combustible material; however, it is also one of the most widely used materials of construction. It is therefore fortunate that wood possesses certain features that allow it to provide satisfactory performance in most building fires. One of these is that it is not easily ignitable, but the most important property of wood is the formation of char after ignition. Charred wood is likely to be found in nearly all structural fires. It is the solid residue (mainly carbon) from the decomposition of wood. It shrinks as it forms and develops cracks and blisters. In combination with a low thermal conductivity, and a protective layer of char, heavy timber sections can provide excellent fire resistance and therefore continue to be used. The concept of sacrificial timber is used in design, i.e. using a larger section of timber than necessary for carrying the design load, with the excess sufficient to protect the member through a given duration of fire. The figure that follows shows, how this concept may be used in design.

Strength reduction in wood begins as soon as it is heated. Compressive strength reduces at a higher rate than tensile strength.

Timber does not expand on heating like steel and concrete and therefore does not threaten adjoining masonry in the same manner.

Masonry

Masonry consisting of either brickwork or of concrete blockwork is inherently stable in fire. The reasons for masonry wall failures are often nothing to do with the fire resistance capability of masonry materials.

Masonry can also suffer integrity failure when fire loads are excessive. Bricks can withstand temperatures of around a 1000 °C and they melt at about 1400 °C. In domestic fires integrity failures are more common.

Most comments about spalling discussed earlier apply to masonry as well.

Glass

The main use of glass in buildings is in glazing for windows and doors. In this role, glass has little resistance to fire and generally cracks very quickly because of the temperature difference across the exposed surfaces. Double glazing does not improve this behaviour significantly. Wire reinforcement does provide relatively greater integrity, however, in general, glazing should not be relied upon to remain intact in a fire.

Gypsum

Dehydrated gypsum is well known as Plaster of Paris, which is a white powder which sets hard after being mixed into a paste with water. In building gypsum plaster and plaster boards are widely used in interior linings and partitions. In addition to the low thermal diffusivity with the large amount of chemically bonded water in gypsum building products allows it to absorb a considerable amount of heat from fires and therefore acts as a cheap and effective fire-retardant material. Once the water of crystallisation has evaporated, gypsum plasterboards have practically no strength left (other than that provided by the fibre glass reinforcement).

Plastics

A large variety of plastics are used in buildings. The main disadvantage is that all plastics are combustible. Certain treatments can increase ignition temperatures and inhibit flame spread, but nothing can be added to make them non-combustible.

Another issue with plastics is that when they melt, they can 'run' and spread the fire. Also, burning plastics can generate significant amounts of (toxic) smoke.

The behaviour of common building contents in fire

According to the National Fire Protection Agency (USA, NFPA) research, after the kitchen and bedroom, the most common fires are in the living room, and these incidents caused 24% of home fire deaths and 10% of the home fire injuries. These numbers are from the U.S. between 2009 and 2013 (NFPA, 2015).

Although the function of the living room has not changed, materials have certainly changed over the years. Over time, it has transitioned from being comprised of natural materials to being dominated by synthetic materials.

In terms of a fire safety perspective the changes in general are:

- The increased use of more flammable synthetic material such as plastics and textiles.
- The increased quantity of combustible materials.
- The use of goods with unknown composition and uncertain flammable behaviour.

The materials that are used in furniture have changed dramatically over the last 30 or 40 years.

Furniture in the 1940's or 1950's was often made of bare wood. Upholstered furniture was usually made of cotton velour over mohair or leather over horsehair. Such furnishings were combustible. Most of the materials were susceptible to smouldering ignition sources such as a dropped cigarette butt, with a few exceptions. They would not be readily ignited by a short-lived flame source such as a common match. Ignition of all but latex foam and kapok took many seconds or even minutes of exposure, and often reluctantly, producing small flames, preferring to smoulder instead.

By the 1960's and 1970's, things were changing, furnishings were often polyurethane foam or cotton padding covered by cotton on cotton/synthetic upholstery fabric. As a result, fire behaviour began to change. Synthetic fabrics and PU foam added smoulder resistance to furnishings but made them more susceptible to ignition by even short-lived open flame sources.

By the 1980's furnishings became almost exclusively polyurethane foam with synthetic coverings that are very difficult to ignite with a smouldering cigarette but are readily ignited by even a small flame. Once ignited, flames could spread quickly, and engulf large chairs or sofas in flames in less than 10 minutes.

Synthetic upholstery materials with their low melting points, melt as they burn, producing molten, burning droplets of materials that fall to the base of the furniture and institute rapidly growing vertical-face fires on the sides of the furniture, as well as "drop-down" damage to floors and carpets beneath.

Today's furniture markedly improved its resistance to the most common type of accidental ignition, for example in the United Kingdom, upholstered furniture should pass flammability tests according to BS 5852 Parts 1, 2 or BS7177/BS6807. These standards include cigarette and small flame ignition tests. In the United States, there are voluntary standards for cigarette ignition of upholstered furniture. Both tests are based on accidental ignition sources, but the trade-off is much worse resistance to flaming sources. Once alight, such furnishings can be completely engulfed in 3 to 5 minutes and be reduced to a charred frame in 10 minutes, while producing very high temperatures and high heat release rates.

Fire and explosion prevention and protection

Structural protection

Introduction

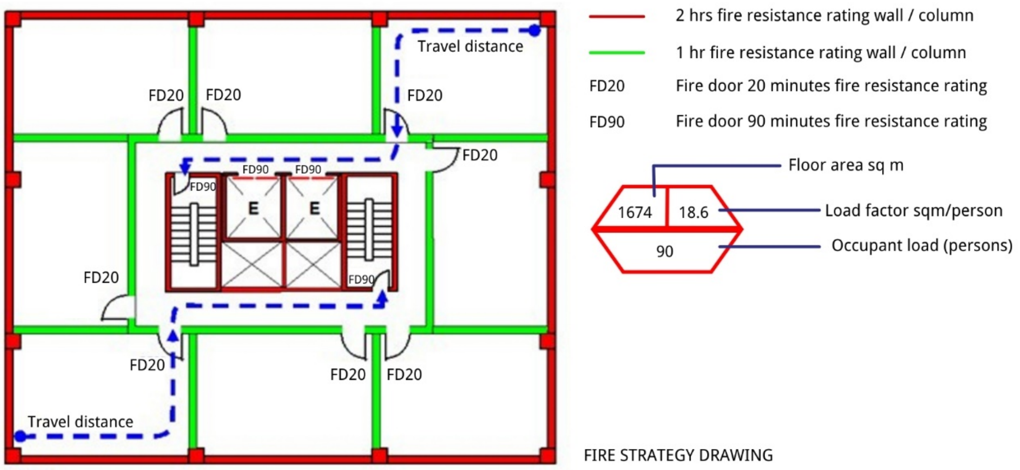
Structural design is the methodical investigation of the stability, strength, and rigidity of structures. The basic objective in structural analysis and design is to produce a structure capable of resisting all applied loads without failure during its intended life.

Structures should be able to withstand all foreseeable loadings and operational extremes throughout the life of the plant. Failure of any structural component could lead to initiation of a major accident. Structural design should consider natural events such as wind loadings, snow and, in the case of plant and equipment, foreseeable process excursions.

There are several methods that can be used to protect structures in the event of fire or explosion, they include:

Compartmentation

Fire *compartmentation* is a form of passive fire protection. It is achieved by dividing the premises/building into fire compartments with the use of fire doors, floors and walls of fire-resisting construction, cavity barriers within roof voids and fire stopping to services that penetrate through these dividing elements (such as cables).



To comply with the legislation/building regulations, effective compartmentation should:

- Prevent the spread of fire, smoke, and toxic gases.
- Break down premises/buildings into manageable areas of risk.
- Provide adequate means of escape enabling time for the occupants to safely evacuate the premises/building.

Openings in Compartments and Fire stopping

Openings which breach compartments should be limited. However, they may be required, for example, when carrying out modifications whereby cables, or pipes may have to pass through. In such cases fire stops will have to be applied to seal any breaches. Mortar or proprietary sealants are often used for this purpose.

Voids and Ducts

Fire and smoke spread in concealed spaces within buildings. Examples of such concealed spaces are attic and roof voids, suspended ceilings and utility conduits. Some voids are inherent in specific types of building construction; others are because of modification or renovation.

Ensuring that the appropriate fire materials are used, and properly installed, are key to ensuring the effectiveness of fire compartmentation in voids.

When considering ductwork, such as those used for heating, ventilation, and air conditioning (HVAC) systems fire dampers are used to prevent the spread of fire and its products.

Structural Steelwork
Carbon steel begins to lose strength at temperatures above 300°C and reduces in strength at a steady rate up to 800°C. It finally melts at about 1500°C.

Passive fire protection materials insulate steel structures from the effects of the high temperatures that may be generated in fire. There are several materials that can be used, including films of intumescent and concrete encasement.

The thickness of spray protection depends on the fire rating required and size of the job. With concrete encasement, the combined action of the steel and concrete can provide high fire resistance.

Segregation and storage of flammable, combustible, and incompatible materials
It is the container that is the primary safeguard in preventing the release of flammables. It therefore must be designed for, and compatible with, the properties (chemical and physical) of the flammable liquid to ensure no leakage if interaction with the container should occur.

The container opening should be equipped with secure, well fitted caps or lids to ensure that liquid or vapour does not escape - even if the container falls over.

Individual containers must be clearly marked to indicate their contents and the degree of flammability.

Flammable liquids storage areas require means to prevent the uncontrolled spread of any spillages or leaks. This is usually achieved by ensuring that the storage area floor is impervious and is enclosed with an impervious sill or low bund wall to contain a volume that is at least 110% of the capacity of the largest container.

Segregation of incompatible substances
Flammable liquids should be stored separately from incompatible substances. For example, the extremely flammable Acetone should never be stored with concentrated Nitric Acid. Mixing them together has resulted in numerous fires and explosions.

Combustible materials, such as packaging, should not be kept in the flammable liquid storage areas. Potentially, this could be the first material to ignite, with the resultant fire being a major threat to the safe storage of the flammable liquid’s containers.

Some substances (such as ammonium nitrate) which, although not combustible themselves, can help other materials to burn rapidly even if air is excluded. When heated in a fire, many of these substances decompose and give off oxygen, which can increase the rate of burning with possible catastrophic consequences.

HSE Guidance "Chemical warehousing: The storage of packaged dangerous substances (HSG71)" gives guidance on the safe storage of incompatible chemicals and includes segregation recommendations.

Hazardous Area Zoning
As previously discussed, Area classification (or zoning) is a method of analysing and classifying the environment where explosive gas atmospheres may occur. The main purpose is to facilitate the proper selection and installation of apparatus to be used safely in that environment, considering the properties of the flammable materials that will be present.

Once the classification has been completed, electrical equipment of a suitable nature can be selected and installed in the relevant area.

Inerting
Involves the partial or complete substitution of the air or flammable atmosphere by an inert gas is a very effective method of explosion prevention. Inerting is normally only considered when the flammable or explosive hazard cannot be eliminated by other means i.e. substitution of flammable material with non-flammable, adjustment of process conditions to ensure substances are below flammable limits. Typical uses are within storage tanks where a

material may be above its flashpoint and within reactor systems when excursions into flammable atmospheres may occur.

Methods of Explosion Relief

Methods of explosion relief include venting, bursting discs and suppression

Ventilation
The first consideration should be to eliminate or minimise the release of dangerous substances. This is done by using closed systems or suitable processing and handling methods. Ventilation should be designed to dilute the concentration of any dangerous substances to below that which could form an explosive atmosphere.

If natural ventilation (by inserting low and high openings in walls) is unable to achieve the required air changes to disperse the dangerous substance then forced (mechanical) ventilation (using fans) should be used in process and storage areas that cannot be sited in the open air.

If the release of dangerous substances is unavoidable, Local exhaust ventilation (LEV) is preferred.

Explosion Vents or Panels
An explosion vent panel is a safety device that is designed to protect equipment or buildings against excessive internal, explosion-incurred pressures. If an explosion occurs, the pressure will be released (sometimes via a fitted duct) as soon as its activation/opening pressure is reached.

Bursting Discs
A bursting disc (also known as a pressure safety disc or a rupture disc is a pressure relief device that protects a pressure vessel, equipment, or system from overpressure. It does so by bursting/rupturing when a pre-determined pressure is reached.

The disc is mounted in a holder and is normally mounted between pipe flanges, although other mounting arrangements are available.

Explosion Suppression

Explosion suppression systems are designed to detect an explosion at its earliest stage (ignition) and to activate (detection) and to quench the explosion (control) before sufficient pressure is generated to cause serious damage.

This is achieved by the rapid injection of a suitable suppressing medium into the flame front. The suppressant is often a dry powder like those used in fire extinguishers. In certain circumstances water may be used.

10.4: Fire risk assessment

The five steps to fire risk assessment

Employers should carry out a fire safety risk assessment and keep it up to date.

Based on the findings of the assessment, employers need to ensure that adequate and appropriate fire safety measures are in place to minimise the risk of injury or loss of life in the event of a fire.

To help prevent fire in the workplace, the risk assessment should identify what could cause a fire to start, i.e. sources of ignition (heat or sparks) and substances that burn, and the people who may be at risk. It follows the principal of the Fire Triangle (Heat, Fuel and Oxygen)

Once the risks have been identified, action can be taken to control them. Consider whether you can avoid them altogether or, if this is not possible, how you can reduce the risks and manage them. Also consider how you will protect people if there is a fire.

Step 1: Identify the hazards

Fire starts when heat (source of ignition) comes into contact with fuel (anything that burns), and oxygen (air). The aim is to keep sources of ignition and fuel apart.

Think about how a fire could start - sources such as heaters, lighting, naked flames, electrical equipment, hot processes such as welding or grinding, cigarettes, matches and anything else that gets very hot or causes sparks.

Think about what could burn - packaging, rubbish and furniture could all burn, just like the more obvious fuels such as petrol, paint, varnish and white spirit. Also think about wood, paper, plastic, rubber and foam. Do the walls or ceilings of a building have hardboard, chipboard, or polystyrene?

Are there any additional sources of oxygen - such as compressed oxygen cylinders.

Consider any structural features that could promote the spread of fire (e.g. open staircases, openings in walls and floors, large voids above ceilings and below floors). Additionally, consider the potential combustibility of any structural features.

Step 2: identify people at risk

Everyone is at risk if there is a fire.

Think whether the risk is greater for some because of when or where they work, such as night staff, or because they're not familiar with the premises, such as visitors or customers. Children, the elderly or disabled people are especially vulnerable.

Step 3: Evaluate, remove, reduce and protect from risk

Evaluate
First, think about what you have found in steps 1 and 2: what are the risks of a fire starting, and what are the risks to people in the area affected and nearby?

Remove and reduce the risk

- Minimise and control ignition sources (such as restricting smoking to designated areas, using permits to work for hot work activities).
- Minimise combustible materials by, for example, good housekeeping - proper and prompt storage and disposal of unwanted materials, keeping low volumes of flammable liquids in workplaces.
- Keep sources of ignition and fuel apart (with fuel in proper storage facilities).
- Secure premises and fuel storage areas (for example, in case of arson).
- Ensure that buildings and structures are properly designed to minimise fire spread (including the effects of any modifications).

Protect

Fire detection and warning

The sooner a fire is detected, and a warning given to staff, the safer it is for everyone. In most workplaces, a fire would quickly be spotted by staff working in or moving around the premises. However, if there are parts of the workplace that are infrequently visited they may be better protected by installing a fire detection system, especially if a fire taking hold in that area could threaten the escape route.

In all but the very smallest workplaces, a mechanical system of raising the alarm in case of fire will be necessary. Any system must be easily operated and audible throughout the workplace.

Any workplaces including sleeping accommodation should be provided with an automatic system for detecting fire and sounding the alarm.

Detection and warning systems must be subject to regular inspection and maintenance.

Workers must be suitably trained in order to:

- Recognise the fire alarm.
- Activate the alarm if necessary.
- Safely evacuate the premises in the event of fire (knowledge of escape route and assembly point).

Firefighting equipment

Most premises are provided with some means of fighting a fire. Unless staff are properly trained, however, they can put themselves and others at risk in using this equipment.

As a general rule, firefighting equipment should only be used to limit the spread of fire to enable safe evacuation. Before tackling any fire, it is vital that the alarm is raised and the fire brigade are called.

Extinguishing equipment must be appropriate for the class of fire in the area, as determined by the risk assessment. It should be suitably sited, that is in conspicuous positions, available at all times for immediate use and fitted on brackets or stands where they will be readily seen by any person following an escape route. It must be inspected and maintained in efficient working order, in accordance with manufacturers guidance or National legislation.

Employers must ensure that workers are trained, as appropriate, in the use of portable fire extinguishers with refresher training as necessary (for example, OSHA requires that employees are re-trained annually). The training should be suitable for the types of emergency that employees may face (for example, the training required for a process plant operator will be different to that required by employees working in an office).

Step 4: Record, plan, inform, instruct and train

A record should be kept of any fire hazards and what you have done to reduce or remove them. Even if the premises are small, a record is a good idea. In the UK recording is required if there are five or more staff or if the premises are licensed.

There should be a clear plan of how to prevent fire and how you will keep people safe in case of fire. If you share a building with others, you need to coordinate your plan with them.

Finally, staff need to be informed of the actions to be taken in the event of a fire. This may involve specialist training for certain roles (for example, acting as a fire warden; use of a fire extinguisher).

Step 5: Review

The assessment should be kept under regular review. Over time, the risks may change (for example new or modification to a building; new processes; new or additional staff.). If you identify significant changes in risk or make any significant changes to your plan, you must tell others who share the premises and where appropriate re-train staff.

Fire detection and alarm systems

Common fire detection and alarm systems and procedures

Factors in design and application of fire detection and alarm systems

Introduction
Fire detection and alarm systems are designed to provide warning to the outbreak of fire, so allowing evacuation and appropriate firefighting action to be taken before the situation gets out of control. Systems may be designed primarily to protect property or life, or to protect against interruption to a client's business from fire; some systems may be designed to achieve any combination of these objectives. It is essential that the designer understands the objective(s) of the system. This places a great responsibility on the designer because each building will present a different set of problems in relation to satisfying the objective. Each fire detection and alarm system therefore must be specifically designed to meet the requirements of the client for each building.

Once the objective(s) has been defined, in designing a system, particular consideration must be given to:

- The type of building.
- Its construction.
- The purpose for which it is being used.

So that in the event of a fire, the fire detection system, combined with appropriate fire prevention procedures, will keep fire risk to a minimum.

Size of building
Size and the layout of your business premises will be a key consideration when deciding upon an alarm system to offer complete coverage and fire protection. Smaller commercial properties tend to be more suited to conventional fire alarms, which will consist of detectors and call points that can be activated manually or automatically to raise

the alarm. These systems use basic fire detection zones to identify which zone the alarm has been triggered as they are wired back to a central control panel.

Larger premises often require much more sophisticated alarm systems. Buildings may have multiple floors and will require at least one fire detector to be placed on every level and in some cases each room, depending on what is set out in their risk assessment.

In huge buildings it saves valuable time to know the exact location of the fire, down to the alarm or call point that was triggered. This can be pinpointed by using addressable fire alarms systems which are programmed so that each device has its own specific location. These alarms can be set up to control a whole host of crucial fire safety features such as shutting down equipment, activating fire suppression equipment and recalling elevators to ground level.

The type of alarm
By far the most important objective of a fire alarm system is to ensure that it alerts all of the people on your premises to danger. If there are a number of people on your premises, particularly members of the public - you may need a way of communicating directly with them. For this a fire alarm system that has a public address system built in would be most appropriate, as it allows you to give specific evacuation instructions whilst also reassuring people.

There may also be vulnerable people on site or people that are hard of hearing. In these cases you must ensure that your alarm system and fire evacuation policy takes into account their safety needs. For people with hearing difficulties, special fire alarms may be required. These can send radio wave signals to pager devices, which vibrate providing warning that there is danger.

Monitoring
If there are times when there is no one present on your premises (for example at night or on weekends) then you may require a monitored fire alarm system. This is particularly important for shops and warehouses where they may be a great deal of stock that needs protecting 24/7. Monitored alarm systems can be set up to notify designated people if the alarm system is triggered or automatically alert the fire brigade.

When designing a fire detection and alarm system, in addition to deciding the type of system, detectors, call points and sounders to be used, etc. there are also other aspects which need to be considered.

These include:

- Measures to limit false and unwanted alarms.
- Method of installation, materials required during installation.
- User training.
- Routine maintenance procedures, and service agreement.

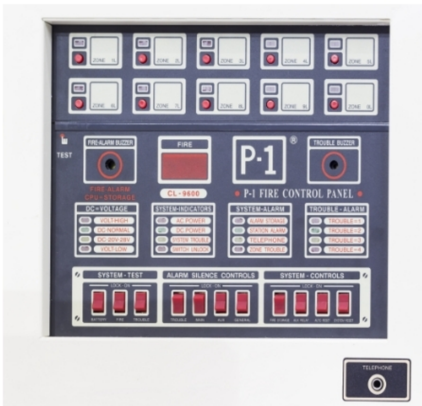
For any system to function reliably and provide problem free service throughout the life of the system, all of these aspects must be considered in the overall system design and plan.

The principal components of fire alarm systems; detection and signalling

Typically, a fire alarm system is made up of the following components:

- **Initiating devices**, capable of placing the system in the alarm state. These can include photoelectric smoke and heat detectors, ionization smoke detectors, heat detectors, in-duct smoke detectors, manually operated stations.
- **Indicating appliances,** whose purpose is to announce building occupants or at a remote location when the system enters the alarm state, such as horns, strobe lights, chimes, bells, or combination uni

- **A control panel**, containing programming and operating electronics and user interface, is fed by standard branch-circuit wiring and contains replaceable circuit cards - one for each zone. This includes an alphanumeric display, showing the state of the system and providing troubleshooting information, and a touchpad so that onsite personnel can silence an alarm or trouble signal, reset the system following an event, and reprogram if necessary.



- **Sealed batteries** like emergency light batteries but listed for fire alarm systems. These are usually 6V batteries wired in series to make up 24VDC for a power-limited system. The batteries can be contained in the control panel or in a separate enclosure. When AC power fails, the batteries take over with no interruption in fire protection. Of course, there is also a charger.
- **Auxiliary devices,** including remote annunciators with LEDs showing the state of the system, an alarm silence switch, and visual LED indication of the zone from which a fire alarm is initiated. Electromagnetic door holders (floor or wall-mounted) are available. In case of alarm, the magnet is de-energized, allowing the door to swing shut. Later, it is reopened manually.

Manual and automatic systems

Manual fire detection

Whatever fire detection is installed in a building, there should always be the option for workers to raise the alarm themselves. This will be in the form of a "pull station" (favoured by the USA) or a "call point" (favoured by Europe and Australasia).

A fire alarm pull station is an active fire protection device, usually wall-mounted, that, when activated, initiates an alarm on a fire alarm system. In its simplest form, the user activates the alarm by pulling the handle down, which completes a circuit and locks the handle in the activated position, sending an alarm to the fire alarm control panel. After operation, some fire alarm pull stations must be restored to the ready position using a special tool or key to deactivate the alarm sequence and return the system to normal.

Manual call points (MCP's) are used to initiate an alarm signal and operate by means of a simple button press. They can form part of a manual alarm system or an automatic alarm system. There will be an indicator on the monitoring unit for visual indication to locate the call point easily, and there should be a visual identifier of the unit which triggered the alarm, typically a mechanical flag which operates on a latch and must be manually reset, e.g. by a key.

Automatic fire detection
Fires can be detected from flame, smoke, or heat. A combination of devices may be needed for best results. There is no perfect fire detector.

The products of combustion that can be used to detect the presence, and give an early warning of fire include:

- Smoke detectors
- Flame detectors
- Heat detectors

Once detected, a fire alarm is automatically triggered from the system control panel, which may also indicate the exact location of the fire.

Smoke detectors
Smoke detection technology ranges from the battery-powered detectors on sale generally to sophisticated visual, camera-based detection systems. *Point detectors* detect smoke at a fixed point. They need to be placed where smoke realistically could travel in the event of a fire. There are two types commonly used, the *optical detector* and the *ionisation detector.*

Optical Point Smoke Detectors detect smoke particles inside a chamber by an increase of light caused by smoke particles or by the smoke particles obscuring a light beam.

Ionisation Point Smoke Detectors use a small radioactive source and detect decreased conduction caused by the ionisation of smoke particles in a detection chamber.

Flame detectors
There are two types:

Infra-red flame detectors: The detector relies on infra-red radiation produced by flames. The level and wavelength of infra-red radiation varies depending on the fuel of the flame being detected. The detector detects a flame within a cone of vision. Flame pattern recognition can be used to distinguish between constant sources of infra-red and flames. Background infra-red radiation can lead to reduced sensitivity and reduced effective detection distances. Careful placement is needed.

Ultra-violet (UV) Flame Detectors: These detectors rely on the effective detection of ultra-violet radiation produced by flames. This is the original type of flame detector and has been largely superseded by other technologies.

Heat detectors
The following definitions are used in this section:

- **Thermal lag:** Thermal lag is the delay of heat transmitted or conducted through a material. Some materials will reflect heat, stop heat from travelling through them and others will absorb it and release it slowly over a period. A material with high heat capacity and low conductivity will have a high thermal lag (e.g. insulation).
- **Eutectic Alloy**: An alloy constructed of different composites that gives the lowest possible melting point. However, some eutectic alloys are formed to provide an alloy where part of it will melt and another part will remain solid, at the same temperature. This temperature is known as the eutectic.

A **heat detector** is a fire alarm device designed to respond when the thermal energy of a fire increases the temperature of a heat sensitive element. The thermal mass and conductivity of the element regulate the rate flow of heat into the element. All heat detectors have this thermal lag. Heat detectors have two main classifications of operation, *"fixed temperature"* and *"rate-of-rise"*.

Fixed Temperature (Point) Heat Detectors: This is the most common type of heat detector. Fixed temperature detectors operate when the heat sensitive eutectic alloy reaches the eutectic point changing state from a solid to a liquid. Thermal lag delays the accumulation of heat at the sensitive element so that a fixed-temperature device will reach its operating temperature sometime after the surrounding air temperature exceeds that temperature.

Rate of rise: Rate-of-Rise heat detectors operate on a rapid rise in element temperature set to a specified temperature rise per minute. The parameters can be set depending on the environment and monitoring required. This type of heat detector can have two heat-sensitive thermocouples/thermistor. One thermocouple monitors heat transferred by convection or radiation. The other responds to ambient temperature. The detector responds when the first's temperature increases relative to the other.

Fixed and portable fire-fighting equipment

Factors in design and application of fixed fire-fighting systems and equipment

Classification of fires

Unfortunately, there is not a universal fire-extinguishing agent and therefore there is a possibility that using types of fire extinguishers on ignited materials or liquids may make the fire considerably worse. Fires have been divided into broad classifications for extinguishing purposes. This will assist in selecting the most effective fire-extinguishing agent to be used, on the most appropriate type of fire and burning material.

The following table highlights the Classes of fire:

Classes of Fire	Types of Fire	Picture symbol	Extinguisher
A	Wood, paper, textiles etc…		• Water • Foam Spray • ABC Dry Powder • Class F Wet Chemical
B	Flammable liquids		• Foam spray • ABC Dry Powder
C	Flammable gases		• ABC Dry Powder
D	Metal		• Class D Powder
F	Cooking oil and fat fires		• Class F Wet Chemical
	Electrical		• ABC Dry powder • Carbon Dioxide

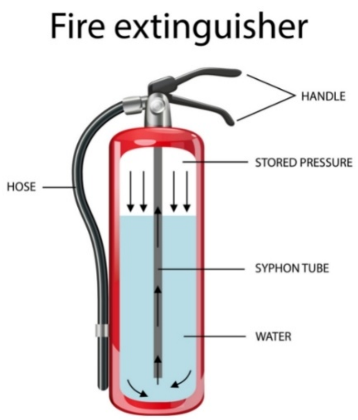
Portable fire-fighting equipment

Water

Water is best for Class A fires (wood, paper, fabric, plastics, etc). It should never be used on burning fat, oil, or electrical applications. Water has a great effect on cooling the fuel surfaces and thereby reducing the pyrolysis rate of the fuel.

A variation on the standard type of water extinguisher involves a "spray" nozzle. It operates at a higher pressure, thus creating a fine spray. This allows for a given quantity of water to have a considerable increase in the surface area presented to the fire, thus makes extinguishing more efficient by more rapid extraction of heat, formation of steam.

A further variation is a "water mist" extinguisher. Water is turned into microscopic particles in the supersonic nozzle. The water mist is drawn to the fire where it cools and suffocates the fire.



Dry Powder
Can be used on fires involving organic solids, liquids such as grease, fats, oil, paint, petrol, etc. but not on chip or fat pan fires. Powder fire extinguishers work chemically interrupting a chain reaction. They act in immediate suffocation because the mono-ammonium phosphate they are generally composed of melts when exposed to combustion temperature. This creates a sticky substance that sticks on the fuel surface, creating at the same time a barrier between the fuel and the oxygen.

Foam
Best for fires involving solids and burning liquids, such as paint and petrol but not suitable for chip or fat pan fires. A foam fire extinguisher cools and suffocates. The foam creates an air-excluding, cooling, continuous layer of vapour sealing, water bearing material that halts and prevents combustion.

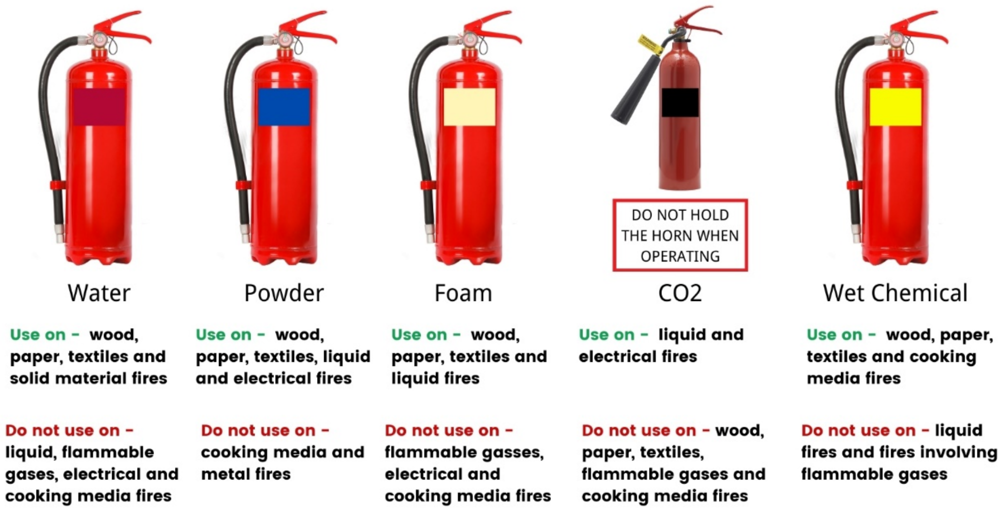
Carbon Dioxide
Best for Live electrical equipment, although it allows re-ignition of hot plastics. Now mainly used on large computer servers, although care must be taken not to asphyxiate people when using the extinguisher in small server rooms. Carbon dioxide extinguisher works by suffocating the fire. Carbon dioxide displaces oxygen in the air.

Wet chemical
Best for Class F fires, involving cooking oils and fats, such as lard, olive oil, sunflower oil, maize oil, and butter. The potassium acetate the extinguisher discharges is transformed into a fine mist.

When that fine mist comes into contact with the oil or grease’s surface, a saponification effect is produced. What does this mean? The creation of a soapy film that seals the surface and separates it from the air. This mist also has a cooling effect because part of these fine drops gets vaporised making oil and grease’s temperatures diminish.

Fire blankets
Fire blankets are made of fire-resistant materials. Best for fires involving both solids and liquids. Particularly good for

small clothing fires and for chip and fat pan fires providing the blanket completely covers the fire, smothers the fire, and prevents oxygen getting to the fire.



It should be noted that the colour coding used for fire extinguishers in the notes is that adopted by the UK. Europe does not generally use the colour code banding.

Australia is similar to the UK.

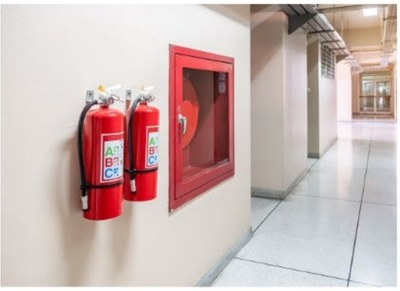
There is no official standard in the United States for the colour of fire extinguishers, though they are typically red, except for class D extinguishers which are usually yellow, water and Class K wet chemical extinguishers which are usually silver, and water mist extinguishers which are usually white. Extinguishers are marked with pictograms depicting the types of fires that the extinguisher is approved to fight. In the past, extinguishers were marked with coloured geometric symbols, and some extinguishers still use both symbols.

Siting of portable fire extinguishers

The following factors should also be considered when siting fire extinguishers:

- Extinguishers should normally be sited on escape routes on all floors at 'fire points'.
- They should be fixed in a location where the extinguisher can be reached quickly. The best place is near a door leading to a place of safety or near a specific fire risk.
- They should be fixed where they can be easily seen. Fixing them inside cupboards or behind doors will only waste valuable time if a fire breaks out.
- Do not place them over cookers or heaters or in places of extreme temperatures, hot or cold.
- Extinguishers should be fixed at an elevated height, so that the carrying handle is 1m from the floor for heavier units (heavier than 4kg) and 1.5m for smaller units.

- Extinguishers should be within reasonable distance from any fire risk (maximum 30 m).
- If you have to travel through doorways, the maximum travel distances need to be reduced.
- The method of operation should be similar for all extinguishers, where possible.
- The occupiers should be capable of handling all the types and sizes recommended.
- Where different types of extinguishers for different risk types are sited together they must be properly labelled to prevent confusion.



Maintenance, training and inspection

Extinguishers in use should be visually inspected monthly for damage and should be serviced once a year. Water, foam and powder extinguishers should be discharged and refilled every five years. CO2 extinguishers should be refurbished after ten years.

Inspections may need to be carried out more frequently in locations where they are likely to suffer damage (for example construction sites; chemical plants).

Training
Fire extinguishers: these units are only useful if workers know how to use them. In some countries (for example, the UK and the USA) it is a legal requirement. However, there are a number of other good reasons for fire extinguisher training:

- It can prevent injuries: an untrained worker may stand too close to the flames or extend their arms near enough to be burned while holding an extinguisher. Or they may try to fight the fire when it is between them and the exit, which training will teach you is extremely dangerous (and can lead to you getting trapped in the building with no means of egress).

- It can limit or prevent property damage: a small fire that can be easily extinguished can quickly turn into a large-scale blaze that engulfs major sections of the building.

- Knowing that they are expected to use fire extinguishers in an emergency, yet not having any training on how to do so, can make staff feel uneasy. It is important for employees to feel safe in the workplace, as this leads to better attitudes and it may even improve productivity.

The typical content of a fire extinguisher training course would include:

- Types of extinguishers.
- Practical use of firefighting equipment.

It may also incorporate:

- Actions to be taken in the event of a fire.
- Classes of fire.
- General good housekeeping.
- Methods of fire spread.
- The theory of combustion.

Fixed firefighting equipment

The basic components are **water source** (such as sea water, well water; domestic water.); a **Pump**, designed to deliver the required flow rate and pressure, and a **Fire water main**, which provides a path to get the water to where it is required (for example: risers in buildings; fire hydrants; sprinkler or deluge heads).

Water systems primarily operate by cooling the fire and are suitable for use in environments containing solid combustible materials such as wood, paper, and textiles (Class A fires).

Sprinkler Systems
A fire sprinkler system is an active fire protection measure, consisting of a water supply system, providing adequate pressure and flow rate to a water distribution piping system, onto which fire sprinklers are connected.

Automatic sprinkler systems are used more than any other fixed fire protection system. The purpose of an automatic sprinkler system is to detect the fire, extinguish or control the fire and to raise the alarm.

Each closed-head sprinkler is held closed by either a heat-sensitive glass bulb or a two-part metal link held together with fusible alloy. The glass bulb or link applies pressure to a pip cap which acts as a plug which prevents water from flowing until the ambient temperature around the sprinkler reaches the design activation temperature of the individual sprinkler head. In a standard wet-pipe sprinkler system, each sprinkler activates independently when the predetermined heat level is reached. Because of this, the number of sprinklers that operate is limited to only those near the fire (in reality, normally one or two will activate), thereby maximizing the available water pressure over the point of fire origin. This also minimizes the water damage to the building or structure.

Deluge Systems
The Deluge system is designed to protect high hazard areas containing a severe fuel hazard with a high heat release rate by bringing many open sprayers into action simultaneously in the event of a fire.

The most common approach of detecting a fire is the use of a sprinkler detection line permanently charged by air. In the event of a fire, the sprinkler detector heads directly affected by the fire will operate. The immediate drop in air pressure within the detector line releases the pressure against the Deluge valve diaphragm unit causing the Deluge Valve to open and discharge water through all the open water spray nozzles to rapidly control and extinguish the fire.

Deluge systems can provide rapid cooling, with the added effect of helping to exclude oxygen from the fire.

Water mist systems
A traditional sprinkler system removes the heat element of the triangle whilst water mist removes both the heat and oxygen elements of the triangle. It achieves this by dispersing water through specially designed nozzles at low, medium, or high pressure. Generally, as system pressure increases, the water droplet size decreases. This, in turn, significantly increases the total surface area of the unit and so leads to production of a greater volume of steam, removing more energy from the fire which generates the steam.

The smaller a water droplet size is, the larger the surface area becomes and the more effective the system becomes in rapidly reducing the temperature and oxygen at the flame front of a fire. This is because the heat absorption capacity of water mist is greater than any other water-based suppression system.

To put it another way, when water is converted to steam - which is what happens to the water droplets in water mist - then quite a lot of energy is used, energy which is taken from the fire which has occasioned the water mist discharge. This reduces the strength of the fire.

Fixed Foam and Powder Systems
Firefighting foam concentrate is added to water and expanded by air to produce either low, medium, or high expansion foam for fire suppression. It works by cooling the fuel to below the combustion temperature, or by starving the fire of oxygen (because of its low density, the foam floats on a flammable liquid's surface to stop the oxygen getting to the fire).

There are numerous types of foam for many firefighting applications, including Class A foams; Class B foams; Synthetic foams (including AFFF: Aqueous Film Forming Foams); and Protein foams (such as Fluoro-protein foam).

Dry powder systems

Dry powders have the advantage of a quick knock-down of fire. Their major disadvantage is that they require a lot of clearing up once an installation has operated.

A dry powder installation consists of dry powder containers linked by pipe work to discharge nozzles covering the areas of risk. When a fire occurs, it is necessary to pressurise the powder so that it is forced through the pipe work and discharge nozzles. This is usually done with CO2.

A line detector is linked to a lever which when actuated allows the head of a CO2 cylinder to be pierced. The carbon dioxide thus released pressurises the dry powder and forces it over the protected area. Dry powder installations can usually be operated either automatically or manually.

Inerting (Gaseous) Systems
Traditional flood systems, such as those using carbon dioxide, where the displacement of air within the enclosure is necessary for their successful operation may be inerting systems. Other specialist agents that are used include FM 200, NOVEC 1230, Argonite and inergen.
These systems work by smothering the fire, and thus excluding the air/oxygen.
They have the advantage of being "clean", and therefore cause little mess or damage to equipment. However, when used in areas where people are working there is a risk of people being asphyxiated. In such situations, automatic activation is generally overridden until people leave the area.
Typical applications include computer rooms, or electrical fires.

Environmental considerations

Water is the most used medium for firefighting. However, several major pollution incidents have occurred when water used for fighting fires has been allowed to reach nearby rivers or water courses.

Firefighting run-off may be polluting due to the actual materials on site, their combustion products and/or the use of fire-fighting foam.

In order to mitigate the effects of fire water runoff, the first step is to assess the likely route of any runoff from the site, then to calculate the likely volumes of fire water, which might result from any incident. The local Fire Services should be involved in the volume estimation and will advise on the quantities and the volume of containment required, based on fire-fighting best practice.

Containment systems
Firefighting water containment should be considered and may be required to protect both surface and foul water drainage systems. They include:

Containment Lagoons and Sacrificial Areas: Lagoons should be constructed which are of a capacity for retention of the area concerned. Areas such as car parks, ornamental gardens or sports fields may be appropriate, providing that they are isolated from the drainage system, can be made secure, and are designed to avoid contamination of groundwater.

Tanks: Permanent or portable tanks are another option for fire water retention. They must be constructed of a material resistant to the substances retained and tanks should be vented.

Penstocks and Shut-off Valves: Shut off valves or penstocks (sluice gates) that can isolate parts of the site in an emergency are another alternative to prevent contaminated water reaching a drain or surface water.

Bunds: Potentially environmentally damaging materials should always be stored in adequately bunded areas. Bunds are normally arranged to hold the total of the tank volume, plus 10%, this being the volume of the initial firefighting or fire protection water or foam. However, much more than this volume would be required to fight a fire. Therefore, bunds cannot normally be relied on as fire water protection, but they may be able to provide temporary containment to gain time.

Means of escape

Factors to consider in provision and maintenance of the means of escape

A means of escape may be defined as: " *the structural means whereby a safe route is provided for persons to travel from any point in a building to a place of safety beyond the building without outside assistance.*"

In the event of fire, people must be able to escape from the workplace in safety.

Modern Building Regulations go a long way to ensuring adequate means of escape, but the following points should be borne in mind:

- With the possible exception of very small workplaces, people should be able to turn away from the point of the fire to escape. If they may have to pass a fire, in a corridor for example, the route may need additional protection by fire-resistant partitioning and/or self-closing fire doors.
- Fire travels up natural chimneys, such as stairways. These will need adequate protection.
- Doors should open in the direction of travel, whenever possible - and particularly if they lead from areas of high risk of fire, if they may be used by large numbers of people or if they are situated at the foot of stairways, creating a risk of crushing.

- All doors on escape routes must be capable of being easily and immediately opened from the direction of escape - including those to the outside.
- Escape routes should be short and lead to the outside or to a 'place of safety' - that is, a place which is adequately protected from the risk of fire by partitions/doors. Generally, two to three minutes is considered a maximum safe time. People with mobility impairments will need to be considered here.
- Escape routes must not be obstructed and should be regularly checked to ensure that they are free from clutter.
- Adequate lighting is vital on escape routes - including alternative means of illumination should the electricity fail in the fire.
- If necessary, signs should be provided on doors and escape routes, clearly pointing the way out. These must comply with standard legislation on type, size and design.

Travel distances

Having established the number and location of people and the exit capacity required to evacuate them safely, it needs to be confirmed that the number and location of existing exits is adequate. This is normally determined by the distance people have to travel to reach them.

When assessing travel distances you need to consider the distance to be travelled by people when escaping, allowing for walking around furniture, etc. The distance should be measured from all parts of the premises (for example, from the most remote part of an office or a shop on any floor) to the nearest place of reasonable safety, which is:

- A protected stairway enclosure (a storey exit).
- A separate fire compartment from which there is a final exit to a place of total safety.
- The nearest available final exit.

Suggested Travel Distances:

Where more than one escape route is provided:

- 25m in higher fire-risk area.
- 45m in normal fire-risk area.
- 60m in lower fire-risk area.

Where only a single escape route is provided:

- 12m in higher fire-risk area.
- 18m in normal fire-risk area.
- 25m in lower fire-risk area.

Stairs, passageways and doors

A staircase that is enclosed throughout its height by a fire resisting structure and doors can sometimes be considered a place of comparative safety. In these cases, the staircase can be known as a ‘protected route’. However, the degree of protection that enables staircases to be considered a place of comparative safety varies for differing building types and is normally defined in the relevant building codes of practice. In such cases, passages should be protected to a similar standard.

Exit doors on escape routes and final exit doors should normally open in the direction of travel and be easy and quick to open without the need for a key. Checks should be made to ensure final exits are wide enough to accommodate the number of people who may use the escape routes they serve.

Emergency lighting and signs

Emergency lighting is lighting for an emergency situation when the main power supply is cut, and any normal illumination fails. The loss of mains electricity could be the result of a fire or a power cut and the normal lighting supplies fail. This may lead to sudden darkness and a possible danger to the occupants, either through physical danger or panic.

Emergency escape lighting is that part of an emergency lighting system that provides illumination for the safety of people leaving a location or attempting to terminate a potentially dangerous process beforehand. In many countries it is either a legal requirement or a building regulation requirement.

Escape route lighting is that part of an emergency escape lighting system provided to ensure that the means of escape can be effectively identified and safely used by occupants of the building.

Fire escape signs are provided to aid escape from wherever people are in a building and will direct them to the final place of safety.



Maintaining fire safety in communal areas

Just like employers, landlords have certain legal obligations when it comes to fire safety and protection of their properties and the safety of people who reside in their premises. However, it is not as simple as ensuring there is a couple of fire extinguishers to hand - fire safety largely depends on the potential risks and the different types of buildings can cause confusion. For example, a building that is used for a single tenancy will differ to one which is shared across commercial and residential lettings.

Often, national legislation requires that landlords carry out fire risk assessments in all areas of their properties. This process will identify any fire hazards and who is at risk and decide if anything needs to be done to remove or reduce that risk.

Typically, private sector landlords will be required to have at least one smoke alarm installed on every storey of their properties and a carbon monoxide alarm in any room containing a solid fuel burning appliance (e.g. a coal fire, wood burning stove). After that, the landlord must make sure the alarms are in working order at the start of each new tenancy.

Signs should be placed detailing actions to be taken in the event of a fire; make sure your residents and visitors know how to react and where their nearest fire assembly point is located; making sure that all residents are able to understand any instruction provided (in one case, a landlord renting out their entire building to non-English speaking residents, but all instructions and signs were in English!).

Landlords should consider placing fire action signs on the inside of individual resident's front doors as well as corridors (on every level), entrance doors and common areas. They may also consider holding residents' meetings to discuss fire safety issues as well as other items and concerns, or to write to each individual resident to inform them formally of the fire safety measures that are in place and ask them to take note of the fire signs around the premises.

Other fire related issues landlords need to consider include:

- Ensuring that all outside doors can be easily opened at all times from the inside.
- Considering introducing a smoking policy in the property.
- Carrying out regular electrical installation safety checks.
- Making sure ALL passages and corridors (escape routes) are kept clear.
- All doors that lead out onto the escape route should be 30-minute fire doors.
- Seeking advice from your local Fire and Rescue Service.
- Premises security with regards to arson.

Emergency evacuation procedures

Introduction

Preplanning for emergencies is vital. An urgent need for rapid decisions, shortage of time, and lack of resources and trained personnel can lead to chaos during an emergency. Time and circumstances in an emergency mean that normal channels of authority and communication cannot be relied upon to function routinely. It is therefore critical that all personnel understand their roles in the event of an emergency.

The objectives of Emergency Plans are to:

- Contain and control incidents to minimise the effects, and to limit damage to persons, the environment and property.
- Implement the measures necessary to protect persons and the environment from the effects of major accidents.

- Communicate the necessary information to the public and to the emergency services and authorities concerned.
- Provide for the restoration and clean-up of the environment following a major accident/incident.

Command Structure
In establishing a command structure organisation should take the following points into account:

- One person should be given responsibility for taking overall charge in the emergency. For major emergencies this would usually be the most senior person on site.
- The roles and responsibilities of those in the command structure should be clearly defined and understood.

Responsibilities of others should be clear, for example the individual(s) responsible for:

- Dealing with media.
- Contacting the local authorities or outside emergency services (such as police, fire brigade).
- Contacting neighbouring industries who may be affected by the emergency.
- Contingency arrangements should be drawn up, in case the person in charge, or those with emergency duties, are unable to carry out their role.

Emergency Fire Plan
An emergency fire plan should be provided. This will be specific to the workplace(s) and will detail the pre-planned procedures in place for use in the event of a fire.

The plan should, as appropriate, contain the following:

- Action on discovering a fire.
- Warning if there is a fire.
- Calling the fire brigade.
- Evacuation of the workplace including those particularly at risk.
- Power/process isolation.
- Places of assembly and roll call.
- Arrangements for vulnerable/disabled personnel.
- Liaison with emergency services.
- Identification of key escape routes.
- The firefighting equipment provided.
- Specific responsibilities in the event of a fire.
- Training required.
- Provision of information to relevant persons.
- Frequency of practice drills.

The emergency plan should be practiced and, if necessary, discussed with the local emergency services. If the building is "shared" (such as a multi-story building used by several employers) often the employers will agree a "shared" plan.

Role of the Fire Marshall
A Fire Marshals role may fall into 2 categories, proactive and reactive.

Proactive duties may include periodically checking that:

- Fire Doors and Fire Exits are closed, clear, unlocked, and ready for use.
- All escape routes are safe, unblocked, and clear.
- Fire extinguishers are sealed and in the correct locations.
- There are fire safety signs clearly in position.
- Fire alarms are clear and unobstructed.
- Emergency lighting is in good working order.
- All persons with disabilities are facilitated in the event of an evacuation using their PEEPs.

Reactive duties may include, on hearing the fire alarm:

- Should you have a Fire Marshal jacket, put it on.
- Start the evacuation of your area.
- Check that your area is empty, and everyone has left.
- Ensure everyone who is struggling to leave the area is assisted and taken out.
- Head to the fire assembly area.
- Take a register of your colleagues (roll call).

Gather information from colleagues and other fire marshals:

- Is everyone accounted for?
- Where is the fire?
- What started the fire?
- Anything else of relevance to the fire service.
- Report the information to the fire officer in charge.

Fire Drills

The reason for conducting a fire drill is to educate employees, and others, in the procedures to be followed in the event of emergency that requires evacuation. Many people will enter and leave buildings through the same entrance. Fire drills provide an opportunity for occupants to locate and use alternative routes under non-threatening conditions. This increases the chances of a successful evacuation during a real emergency.

Fire drills may be required by codes, regulations, good practice, insurance requirements or as a policy of the employer but good practice suggests fire drills should be held as a minimum at least twice a year.

Training

Suitable arrangements need to be in place for training individuals on the installation in emergency response. The type of training required depends upon the role of the individual in the event of an emergency. All staff, as well as contractors and visitors to the premises need to be advised of the types and sounds of the fire alarms and the actions to be taken if the alarms sound, including the location of their assembly points. This information may be given as part of a health and safety induction training course.

Personal Emergency Evacuation Plans (PEEPs)

A PEEP is a Personal Emergency Evacuation Plan. It is a bespoke 'escape plan' for individuals who may not be able to reach an ultimate place of safety unaided or within a satisfactory period in the event of any emergency.

PEEPs may be required for staff with:

- Mobility impairments
- Sight impairments
- Hearing impairments
- Cognitive impairments

The following is an example of a PEEP plan:

PERSONAL EMERGENCY EVACUATION PLAN			
Name:	Jill McDermott		
Department:	Healthy and Safety Office		
Building:	Orchard Business Estate – Unit 4		
Room number and floor:	Room 8 – 10, Floor 3		
Ext:	2253		
AWARENESS OF PROCEDURE			
Jill is informed of a fire evacuation by: (please tick ✓ relevant box)			
Existing alarm system ☑	Visual alarm system ☐		
Pager device ☐	Other (please specify) ________		
DESIGNATED ASSISTANCE			
The following have been designed to give Jill assistance to get out of the building in an emergency			
Name:	Diane Bird		
Contact details (Building, Rm No & Ext)	Orchard Business Estate – Unit 4 – Room 8-11 – Ext 2266		
Name:	Arthur Todd		
Contact details (Building, Rm No & Ext)	Orchard Business Estate – Unit 4 – Room 8-14 – Ext 2268		
METHODS OF ASSISTANCE (e.g., Transfer procedures, methods of guidance, animal assistance etc.)			
Diane and/or Arthur will act as Jill's "buddy" and accompany Jill down the stairs			
EQUIPMENT PROVIDED (including means of communication)			
A powerful torch, High vis jacket			
PERSONAL EVACUATION PROCEDURE (A step by step account beginning with the first alarm)			
1	On hearing the alarm Jill will proceed to the fire exit		
2	Jill will wait at the refuge point until everyone passes and the stairs are clear, then walk down the stairs assisted by his "buddy" using the torch if necessary		
3	The Fire Marshall will inform the Fire Liaison Officer that Jill and his "buddy" are proceeding down the stairs slowly		
4	The staircase is fire protected and provide Jill with at least 30 minutes protection to descend the stairs and reach a place of safety		
MONITOR AND REVIEW			
This procedure will be rehearsed during fire drills and will be reviewed annually			
Signed by Manager:		Date:	
Signed by Individual:		Date:	

10.5: Dangerous substances

Industrial chemical processes

The effects of temperature, pressure and catalysts on rates of chemical reactions

Introduction

The chemical process industry includes those manufacturing facilities whose products result from:

- Chemical reactions between organic materials, or inorganic materials, or both.
- Extraction, separation, or purification of a natural product, with or without the aid of chemical reactions.
- The preparation of specifically formulated mixtures of materials, either natural or synthetic.

Examples of processes include:

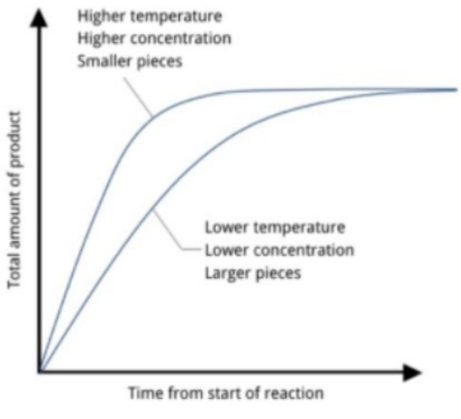
- Haber process - chemically binding gaseous nitrogen from the atmosphere to make ammonia.
- Smelting - chemically enhancing metals.
- Disinfection - chemical treatment to kill bacteria and viruses.
- Pyro-processing - using heat to chemically combine materials, such as in cement.
- Crude oil refining - to separate crude oil into component parts such as gasoline and diesel.

Factors affecting rate of chemical reaction

Temperature

Increasing the temperature of a system increases the average kinetic energy of its constituent particles. As the average kinetic energy increases, the particles move faster, so they collide more frequently per unit time and possess greater energy when they collide. Both factors increase the reaction rate. Hence the reaction rate of virtually all reactions increases with increasing temperature. Conversely, the reaction rate of virtually all reactions decreases with decreasing temperature. For example, refrigeration retards the rate of growth of bacteria in foods by decreasing the reaction rates of biochemical reactions that enable bacteria to reproduce.

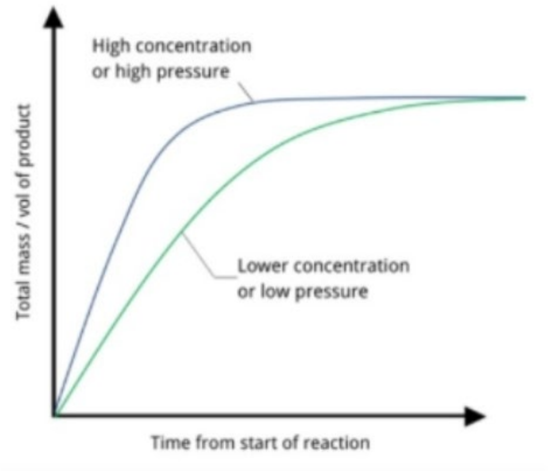
The graph that follows summarises the differences in the rate of reaction at different temperatures, concentrations, and size of pieces. The steeper the line, the greater the rate of reaction. Reactions are usually fastest at the beginning when the concentration of reactants is greatest. When the line becomes horizontal, the reaction has stopped.



Pressure

The rate of a chemical reaction can be changed by altering the concentration of a reactant in solution, or the pressure of a gaseous reactant. If the concentration or pressure is increased:

- The reactant particles become more crowded.
- There is a greater chance of the particles colliding.
- The rate of reaction increases.



Catalysts

The rate of a reaction can be increased by adding a suitable catalyst. A catalyst is a substance which changes the rate of reaction but is unchanged at the end of the reaction.

Only a very small amount of catalyst is needed to increase the rate of reaction between large amounts of reactants.

A catalyst is specific to a particular reaction:

- Different catalysts catalyse different reactions.
- Not all reactions have suitable catalysts.

The table that follows summarises some common catalysts used in industry and the reactions they catalyse.

Catalyst	Reaction catalysed
Iron	Making ammonia from nitrogen and hydrogen
Platinum	Making nitric acid from ammonia
Vanadium (V) oxide	Making sulfuric acid

Heat of reaction in terms of exothermic and runaway reactions

Exothermic reactions

These are reactions that transfer energy to the surroundings. The energy is usually transferred as heat energy,

causing the reaction mixture and its surroundings to become hotter. The temperature increase can be detected using a thermometer.

Some examples of exothermic reactions are:

- Burning.
- Neutralisation reactions between acids and alkalis.
- The reaction between water and calcium oxide.

Endothermic reactions

These are reactions that take in energy from the surroundings. The energy is usually transferred as heat energy, causing the reaction mixture and its surroundings to get colder. The temperature decrease can also be detected using a thermometer. Some examples of endothermic reactions are:

- Electrolysis.
- The reaction between ethanoic acid and sodium carbonate.
- The thermal decomposition of calcium carbonate in a blast furnace.

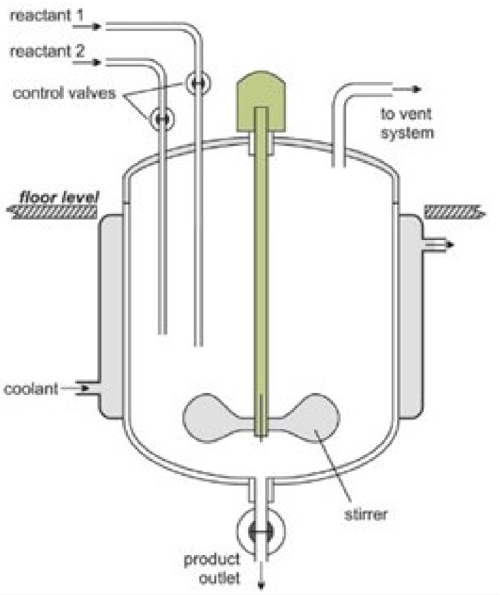
Runaway reactions

There are two main methods of operation with respect to industrial chemical reactions:

- **Batch:** Where each chemical reaction is carried out separately with fixed quantities of materials. When the reaction is complete, the process is stopped. The reactor is recharged, and a fresh reaction starts when the next batch of product is required. Most industrial batch reactors require stirring and cooling.

- **Continuous:** Where the reactants flow into a vessel and products flow out so that the reaction can operate for long periods of time until the flow of reactants is stopped.

Continuous operation is primarily used for large scale production.



A *runaway reaction* is a chemical reaction over which control has been lost. It continues to accelerate in reaction speed until it either runs out of reactants or the vessel containing it overpressures, losing containment - frequently with high risk of injury and equipment damage.

An exothermic reaction can lead to thermal runaway, which begins when the heat produced by the reaction exceeds the heat removed. The surplus heat raises the temperature of the reaction mass, which causes the rate of reaction to increase. This in turn accelerates the rate of heat production. An approximate rule of thumb suggests that reaction rate - and hence the rate of heat generation - doubles with every 10 °C rise in temperature.

Thermal runaway can occur because, as the temperature increases, the rate at which heat is removed increases linearly but the rate at which heat is produced increases exponentially. Once control of the reaction is lost, temperature can rise rapidly leaving little time for correction. The reaction vessel may be at risk from over-pressurisation due to violent boiling or rapid gas generation. The elevated temperatures may initiate secondary, more hazardous runaways or decompositions. An over-pressure may result in the plant failing catastrophically resulting in blast or missile damage.

Effect of scale

The scale on which you carry out a reaction can have a significant effect on the likelihood of runaway. The heat produced increases with the volume of the reaction mixture, whereas the heat removed depends on the surface area available for heat transfer. As scale and the ratio of volume to surface area, increases cooling may become inadequate. This has important implications for scale-up of processes from the laboratory to production. You should also consider it when modifying a process to increase the reaction quantities.

Incidents occur because of:

- Inadequate understanding of the process chemistry and thermo chemistry
- Inadequate design for heat removal
- Mischarging of reactants
- Inadequate temperature control
- Inadequate agitation
- Inadequate maintenance
- Raw material quality
- Inadequate control systems and safety systems
- Inadequate operational procedures, including training

Case Study 1
Bhopal, India, 1984

The Bhopal, India, accident, on December 3, 1984, resulted in the death of more than 2000 civilian casualties.

The Bhopal plant is in the state of Madhya Pradesh in central India. The plant was partially owned by Union Carbide and partially owned locally. The nearest civilian inhabitants were 1.5 miles away when the plant was constructed. Because the plant was the dominant source of employment in the area, a shantytown eventually grew around the immediate area.


Image source - https://en.wikipedia.org/wiki/Bhopal_disaster

The plant produced pesticides. An intermediate compound in this process is methyl isocyanate (MIC). MIC is an extremely dangerous compound. It is reactive, toxic, volatile, and flammable. Individuals exposed to concentrations of MIC vapours above 21 ppm experience severe irritation of the nose and throat. Death at large concentrations is due to respiratory distress. MIC reacts exothermically with water. Although the reaction rate is slow, with inadequate cooling the temperature will increase and the MIC will boil, giving rise to a potential runaway reaction. MIC storage tanks are typically refrigerated to prevent this problem. The unit using the MIC was not operating because of a local labour dispute.

Somehow a storage tank containing a large amount of MIC became contaminated with water or some other substance.
A chemical reaction heated the MIC to a temperature past its boiling point. The MIC vapours travelled through a pressure relief system and into a scrubber and flare system installed to consume the MIC in the event of a release. Unfortunately, the scrubber and flare systems were not operating, for a variety of reasons.

An estimated 25 tons of toxic MIC vapour was released. The toxic cloud spread to the adjacent town, killing over 2000 civilians, and injuring an estimated 20,000 more. No plant workers were injured or killed. No plant equipment was damaged.

Methods of controlling exothermic and runaway reactions
Before control measures can be implemented, the process hazards must be determined. To determine the hazards of a reaction, you need information on the chemistry and thermo chemistry of the reaction.

This includes:

- The possibility of thermal decomposition of raw materials, intermediates,
- Products and by-products.
- Whether exothermic runaway can occur.
- The rate and quantity of heat and gas produced by the reaction.

There is no standard procedure that can be followed for all reactions - the aim is to obtain the data you need to assess the risk adequately. To avoid undue time and effort, any investigation should reflect the complexity of reaction and the size of the risks involved.

Once you know what the risks are, you can select the measures to ensure safe operation. You can ensure safe operation in a number of ways, by using:

- Inherently safer methods, which eliminate or reduce the hazard.
- Process control, which prevents a runaway reaction occurring.
- Protective measures, which limit the consequences of a runaway.

Inherent safety
Where possible, you should first eliminate or reduce hazards by inherently safer design.

For example:

- Replace hazardous materials with safer ones.

- Have less un-reacted material in the reactor, e.g. using a continuous process instead of a batch reactor.
- Use a semi -batch method (in which one of the raw materials is added over time) instead of a batch process.
- Use a heating medium which has a maximum temperature that is too low for the reaction mixture to decompose.

Process control

Process control includes the use of high integrity temperature and pressure rise sensors, linked to alarms, trips and other control systems that either take automatic action (such as process shut down or venting) or allow for manual intervention to prevent the conditions for uncontrolled reaction occurring. Effective cooling systems (such as vessel water jackets, or external heat exchangers/cooler); controlling the rate of reactant addition; possibly pre-chilling of reactants and effective mixing/agitation of reactant inventory also assists in minimising the risk of runaway reactions. Specifying such measures requires a thorough understanding of the chemical process involved, especially the limits of safe operation.

Protective measures

Protective measures do not prevent a runaway but reduce the consequences should one occur. They are rarely used on their own as some preventive measures are normally required to reduce the demand upon them. As they operate once a runaway has started, a detailed knowledge of the reaction under runaway conditions is needed for their effective specification.

You can:

- Design the plant to contain the maximum pressure.
- Fit emergency relief valves and ensure vented material goes to a safe place.
- Crash cool the reaction mixture if it moves outside set limits.
- Add a reaction inhibitor to kill the reaction and prevent runaway.
- Dump the reaction into a quenching fluid.

Case Study 2

Process reactor disaster, Jacksonville (2007)


Image source - https://en.wikipedia.org/wiki/T2_Laboratories_explosion_and_fire

On December 19, 2007, a process reactor containing six tons of gasoline additive blew apart in Jacksonville, FL, killing four employees and injuring 28 people.

A loud jet engine-like sound drew startled attention from businesses neighbouring the T2 Laboratories chemical plant one afternoon in December 2007. Eyewitnesses reported high pressure venting from the top of a 2,450-gallon batch reactor designed to produce a specialized gasoline additive.

Within moments, the reactor violently ruptured with a force equivalent to 1,420 pounds of TNT. "The incident at T2 Laboratories included one of the most powerful explosions that the CSB (U.S. Chemical Safety and Hazard Investigation Board) has ever investigated, a blast that was felt 15 miles away in downtown Jacksonville (FL)," said CSB chairman John Bresland.

Four T2 workers, including a company co-owner were killed in the blast. Four other T2 employees and 28 workers at nearby businesses were also injured.

The blast damaged other businesses within one quarter mile of the facility. Four damaged buildings were subsequently condemned. Debris landed up to one mile away.

A report issued by the CSB in September 2009 blamed the disaster on a runaway exothermic reaction following a breakdown in the reactor's cooling system. No emergency backup to the primary cooling system was available.

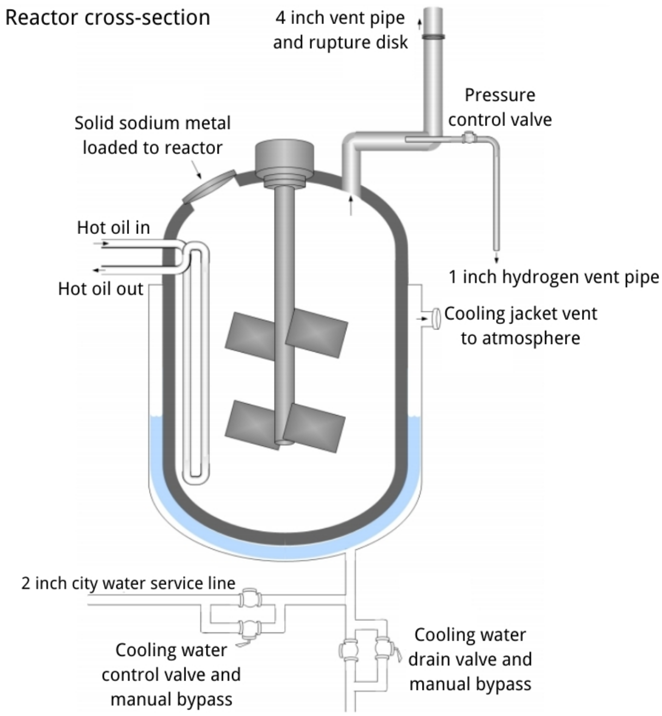


Image source - https://www.csb.gov/userfiles/file/t2%20final%20report.pdf

CSB investigators determined that insufficient cooling was the only credible cause for this incident, ruling out cross contamination, wrong concentration of raw materials, local concentration of chemical within the reactor and application of excessive heat.

"We likely had a cooling system failure," Hall said. "They were unable to apply sufficient cooling, leading to the result we had."

Witness statements confirm that the process operator reported a cooling problem shortly before the explosion. The cooling system lacked design redundancy, making it susceptible to single point failures.

Employees indicated that T2 did not perform preventive maintenance on the cooling system, replacing components only after failure. On at least one prior occasion, the reactor cooling drain valve failed during operations and required repair. Formation of mineral scale inside the jacket could have interfered with heat removal.

CSB conducted laboratory tests based on the T2 chemical recipe using a small sample size to minimize potential hazards. Two exothermic reactions were observed. The first reaction occurred at about 350 degrees as desired. A second more energetic reaction occurred when the temperature exceeded 390 degrees.

Pressure from that second reaction overwhelmed the reactor's pressure relief system designed for normal operating conditions. The CSB report stated that it was unlikely the T2 owners were aware that reaction would occur.

The storage, handling, and transport of dangerous substances

Dangerous substances are any substances used or present at work that could, if not properly controlled, cause harm to people as a result of a fire or explosion or corrosion of metal. They can be found in nearly all workplaces and include such things as solvents, paints, varnishes, flammable gases, such as liquid petroleum gas (LPG), dusts from machining and sanding operations, dusts from foodstuffs, pressurised gases and substances corrosive to metal.

Employers should:

- Find out what dangerous substances are in their workplace and what the risks are.
- Put control measures in place to either remove those risks or, where this is not possible, control them.
- Put controls in place to reduce the effects of any incidents involving dangerous substances.
- Prepare plans and procedures to deal with accidents, incidents and emergencies involving dangerous substances.
- Make sure employees are properly informed about and trained to control or deal with the risks from the dangerous substances.

Storage methods and quantities

Bulk storage
Equipment and supplies stored in a warehouse in large quantities are described as bulk storage. Unlike bin storage, goods stored in bulk storage often use original containers. The term is also widely used in storage of liquids, such as petroleum products, in tanks, unlike drum or packaged storage. This kind of storage is generally used for materials delivered in large quantities.

Bulk storage of raw materials, intermediate and finished products is commonplace in manufacturing industries. An intermediate product is a product that might require further processing before it is saleable to the ultimate consumer. For example, in crude oil refining intermediate products include those such as gas oils; asphalt; diesel and kerosene. Such products will usually be stored in large storage vessels.

Drum storage
Warehouses and drum stores that have not been subject to an adequate dangerous substance storage assessment may have no defined storage system or may have an unsuitable system such as an alphabetical storage system.

The following is a non-exhaustive list of examples of inadequate storage systems and practices commonly found in warehouses and drum stores:

- Absence of a suitable vehicle and pedestrian traffic management plan including defined forklift truck routes with appropriate speed limits, etc.
- Emergency exits obstructed by substance containers.
- Drums stored on damaged, or inadequately secured racking or on damaged pallets.
- Warehouse racking not suitably designed or constructed to withstand the anticipated loading of containers placed on it.
- Absence of secondary containment and spill kits.

- Inadequate / no emergency response plan for dealing with incidents such as liquid spills, toxic gas releases or fires.
- Chemicals stored by poorly chosen categories, such as all acids (inorganic and organic, strong oxidizers) together; all organics stored together.



Segregation
Incompatible chemicals need to be properly segregated according to the chemical hazard class ensuring that like chemicals are stored together and away from other hazard chemical groups.

Segregation in this manner will greatly reduce or even eliminate accidental adverse reactions that may occur due to container breakage in the storage areas. When segregating chemicals by hazard class it is important to ensure that all the hazardous properties associated with the chemicals are identified.

Many chemicals have multiple hazards and a decision must be made as to which storage location within the warehouse or drum store is the most appropriate for each individual chemical. Normally the storage area will be determined by the more hazardous property of the chemical and having assessed the consequences in the event of an accident in the storage area. For example if a chemical is both flammable and corrosive it would be appropriate for the chemical to be stored with other flammables. However if a chemical is both flammable and very toxic then other factors need to be considered before selecting the appropriate storage area, such as the physical properties of the chemical and the quantity being stored.

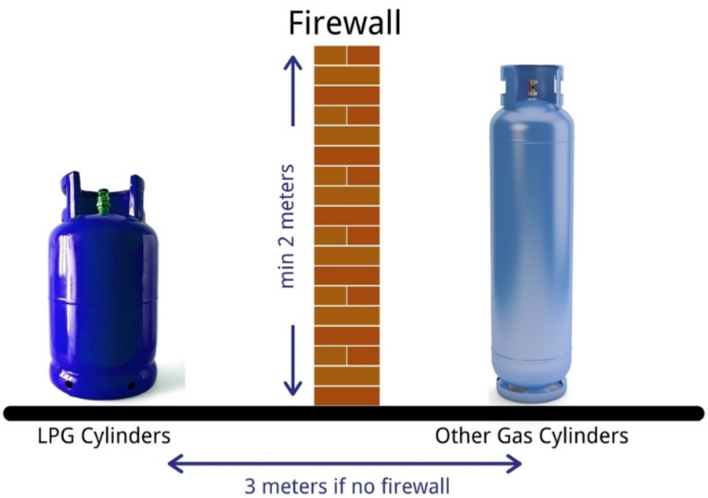
If the chemical emits very toxic gases or vapours then the chemical may need to be isolated within the flammable storage area. There will always be some chemicals that will not fit neatly in one category or another, but with a proper identification of the chemical hazards and assessment of consequences of an accident release using the information available in the SDS, most chemicals should be assigned to appropriate storage areas.

Storage issues
Warehouses and drum stores should have dedicated set down areas for incoming chemicals where the chemicals containers can be inspected and associated safety documentation can be retained.

Preferable, gas cylinders should be stored outside. If stored in a building, they should be securely stored on a flat dry surface in an adequately ventilated building or part of a building specifically reserved for this purpose. Cylinders should be protected from external heat sources that may affect their mechanical integrity and should be stored such that they are not at risk from vehicle impact. Gas cylinders should also be stored away from sources of ignition and other flammable materials, due to the potential for explosion.

Cylinders should be stored vertically and chained to prevent toppling. Full and empty cylinders should be stored separately.

LPG cylinders should not be stored within 3 metres of other cylinders, unless segregated by a firewall.



Leakage and spillage containment

Bunding
Secondary containment (e.g. a bunded area) should be put in place to minimize the spread of any chemical spillage within a storage area. If the storage area does not have built in secondary containment, then the use of specialised chemical cabinets, individual container bunded trays, bunded pallets, should be considered.

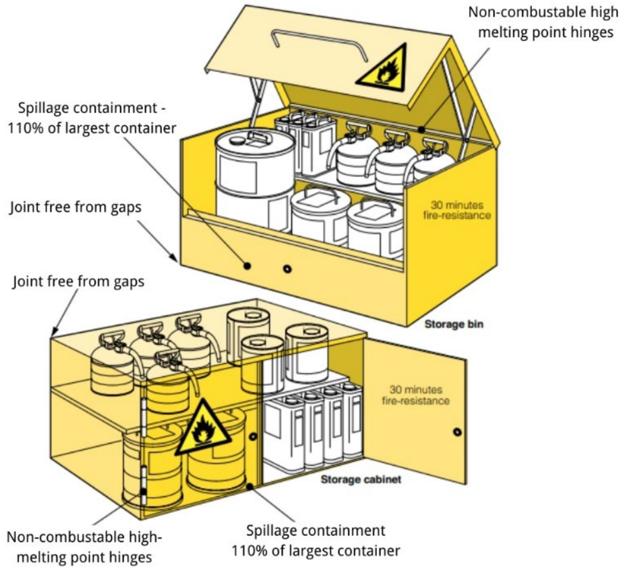


Image source - https://www.hse.gov.uk/pubns/priced/hsg51.pdf

For bulk storage vessels bunds are normally built around the vessel, or group of vessels.

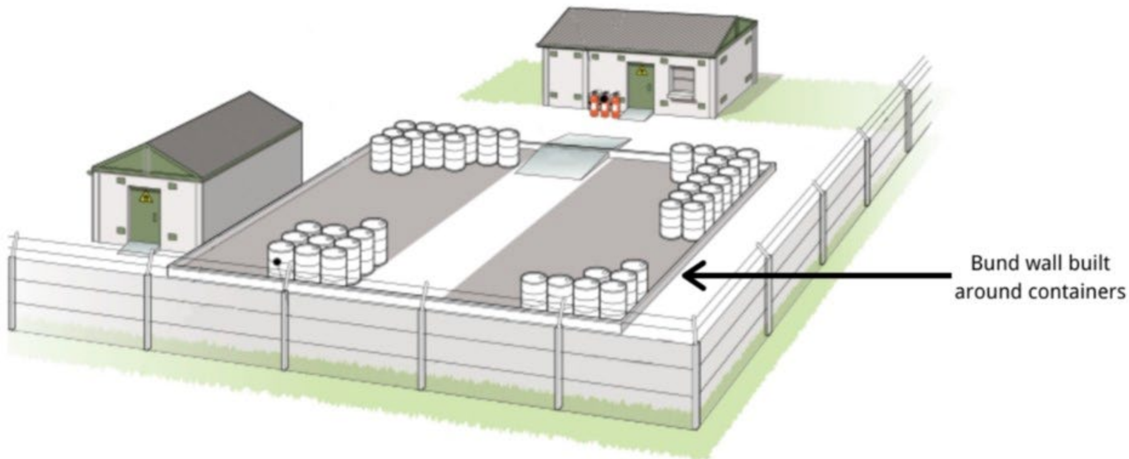


Image source - https://www.hse.gov.uk/pubns/priced/hsg51.pdf

The general principles of a bund design are it must:

- Be able to hold 110% of the vessel content.
- Have impermeable base and walls.
- Have walls strong enough to contain the hydrostatic head of the fluid.
- Have walls high enough to contain "jet" fluid releases.
- Not have pipe work passing through the walls.
- Have a suitable drain for controlled release of rainwater.
- Be protected from any nearby traffic movement.

Filling and transfer
Where dangerous substances are transported to a storage area or carried or conveyed from a storage area or between work areas, they should be carried in closed vessels or conveyed in a totally closed system incorporating pipelines and pumps or similar appliances. The contents of pipes fill points and discharge points should be identified. Where it is not reasonably practicable to use a totally enclosed system, dangerous substances should be carried or conveyed in closed containers or vessels that minimise the risk of spills or releases.

Loading and unloading facilities should be designed, located, and operated to avoid or minimise the risks of fire and explosions at either the transfer facility or the storage installation. The facility should include measures to minimise the risks of leaks, spills and overfilling plant and equipment.

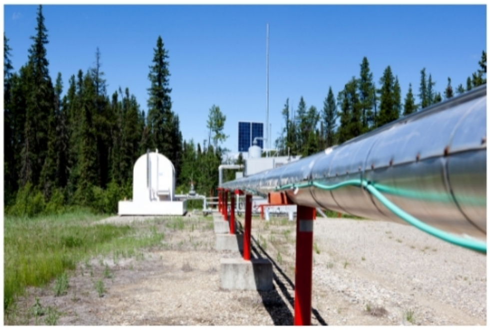
Protective measures, such as physical barriers, will help to prevent damage to containers, vessels, pipe work and other equipment. Systems of work or explosion protected vehicles may be necessary when vehicles are used in or near to storage areas.

Unloading facilities should be designed and operated to minimise the risks of a fire, an explosion or the unintended release of a dangerous substance arising from the inadvertent mixing of incompatible materials.

Such events may occur if a dangerous substance is sent to the wrong tank; if the contents of a delivery vehicle are not the same as the dispatch note or are out of specification; or if a tank is used to store a new material before the residues of the previous contents are adequately cleaned out. The risks may be controlled by measures such as: clear labelling of transfer lines; provision of dedicated transfer lines rather than temporary flexible hoses with complex valve manifolds; use of different types of couplings for incompatible products; simple checks on the contents of incoming road tankers and written systems of work concerning tank cleaning.

The storage and handling of dangerous substances

Flow through pipelines
Pipeline transfer is the most common and economical means of transferring materials. Data from 2014, gives a total of slightly less than 2,175,000 miles (3,500,000 km) of pipeline in 120 countries of the world. The United States had 65%, Russia had 8%, and Canada had 3%, thus 75% of all pipeline was in three countries.



A variety of dangerous materials are transferred through pipelines, including:

- **Crude oil**: pipelines are made from steel and are often buried when travelling long distances.
- **Natural gas:** pipelines are constructed of carbon steel.
- **Highly toxic ammonia** is one of the most dangerous substances to be transported through long-distance pipelines, but accidents have been rare.
- **Hydrogen.**
- **Pressurised hot water** or sometimes steam.

To function effectively, pipelines must be properly maintained. Regular cleaning and maintenance of a pipeline can minimise the potential for corrosion, and thus leakage.

The protection of vulnerable pipelines against sabotage, illegal tapping and terrorist action combined with the detection of leaks in buried pipelines, etc. can be mitigated by a dual-purpose Pipeline Security & Leak Detection system utilising the same fibre-optic cable throughout the pipeline. This system allows the detection of illegal tapping or sabotage of the pipeline, whilst also providing the benefit of real-time monitoring against any rupture or leaks.

The principles of filling and emptying containers
Transferring a liquid from one metal container to another may result in static electrical sparks. To prevent the build-up of static electricity and prevent sparks from causing a fire or explosion, it is important to bond metal dispensing and receiving containers together before pouring. Bonding is done by making an electrical connection from one

metal container to the other. This ensures that there will be no difference in electrical potential between the two containers and, therefore, no sparks will be formed.

The best way to bond containers is to securely attach a special metal bonding strap or wire to both containers.

In the flammable liquid storage and dispensing area, ground dispensing drums. Grounding is done by connecting the container to an already grounded object that will conduct electricity. This could be a buried metal plate, a metallic underground gas piping system, metal water pipes or a grounded, metal building framework. Bonding both containers and grounding one of them "drains off" static charges and prevents the discharge of sparks. All grounding and bonding connections must be bare metal to bare metal. Remove all dirt, paint, rust, or corrosion from points of contact.

Other factors in the formation of static are filling rate and splash fill or turbulence generated during the filling rate. These can be minimised by reducing the filling rate and extending the filling arm to the bottom of the receiving container, or "bottom filling" (as is mainly the case with road tanker filling nowadays).

When emptying containers for disposal or re-use, it is essential to ensure that they are properly cleaned. This may be achieved by water washing, steam cleaning or some other appropriate method. For containers which have stored flammable materials it is important that not only residual liquid has been removed but also residual vapours (a gas test can confirm this).

When pumping materials from larger closed containers, care must be taken to ensure that all air is not removed from the container, thus pulling a vacuum, and possibly causing the container to implode (vacuum valves may be fitted to prevent this).

The image that follows shows a typical arrangement in a process work area where flammable liquids are handled and transferred. Note the ventilation ducts, vent, spillage bund and metered discharge line (to bottom of container).

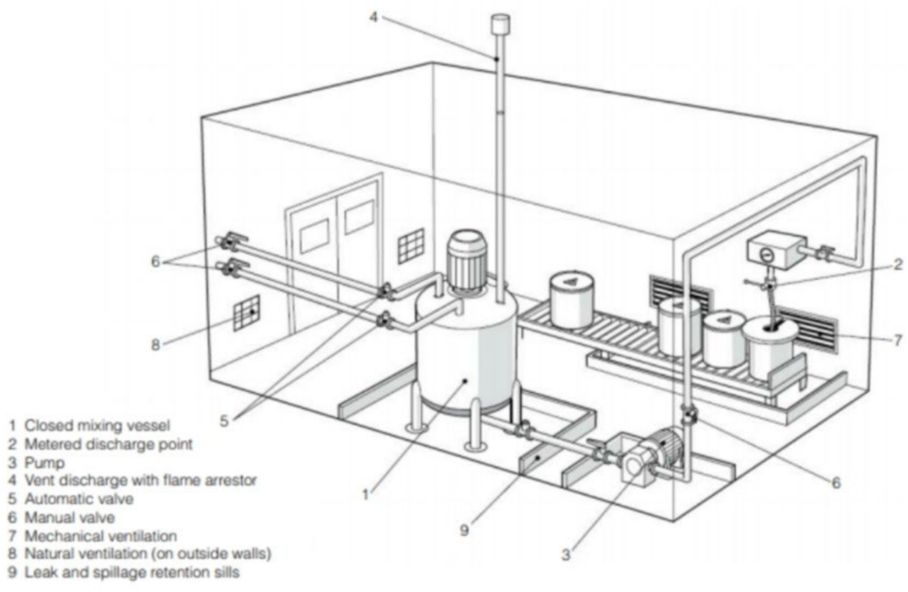


Image source - https://www.hse.gov.uk/pubns/priced/hsg140.pdf

The principles of dispensing, spraying and disposal of flammable liquids

Dispensing

Dispensing and decanting should be carried out in a way which reduces spills and dangerous releases of flammable vapours. The need for these operations should be assessed and, where possible, minimised using enclosed transfer systems. If an enclosed system cannot be used, the containers should be designed to minimise spillage, release of vapour and the effects of fire.

Small safety containers are available which incorporate the following features:

- Metal or heavy-duty plastic construction
- Pouring and/or filling apertures sealed with self-closing spring-loaded caps
- Pouring and/or filling apertures fitted with flame arresters
- Hoses or other aids when dispensing into small openings
- Carrying handles for containers with a capacity greater than approximately 2.5 litres

Open-topped cans and buckets are not suitable for handling or storing flammable liquids as they increase the risk of spillage and the release of vapours. Drums should be provided with secure closures that can withstand the expected handling conditions without leaking. Drums with large removable ends are not normally suitable for flammable liquids.

Spraying

Spraying is the most widely used method in industry of applying paints, varnishes, lacquers, and other coatings. Many of these coatings are flammable liquids which, when sprayed, may create a flammable atmosphere leading to the risk of fire or explosion.

Fires or explosions are likely to occur when vapours or liquids are released into areas where there may be an ignition source, or when an ignition source is introduced into an area where flammable liquids are being used. For example, if spraying is carried out in a workshop where someone is smoking, welding, or using unprotected electrical equipment, then the vapour will ignite, causing a fire or explosion. Similarly, if someone takes an ignition source such as a lighted cigarette or an unprotected light into a spraying area, then again fire or explosion may result.

In spraying, liquid is converted into a mist of droplets which is directed onto a surface to produce an evenly distributed film of the required thickness and texture. Not all the liquid sprayed is deposited on the work piece. Over 50% may be lost as overspray or bounce back. These vapours may hit other surfaces - walls, floors, and clothing - leaving flammable deposits. Even when these deposits are dry, they may still be flammable.

Flammable liquids can pose a health hazard if they are ingested, come into contact with skin or eyes, or if their vapours are inhaled. Serious health hazards are associated with the spraying of two-pack paints and lacquers containing isocyanates.

The usual way to control the flammable vapours arising from spraying processes is to use a ventilated spray booth or enclosure.

Its purpose is to:

- Prevent the escape of vapours into the workplace
- Prevent contamination of the workplace by overspray
- Protect the health of workers
- Provide separation from sources of ignition and to prevent the spread of fire
- Prevent contamination of the work piece by dust and grease from the work environment

A spray booth or enclosure should be of half-hour fire-resisting construction. If spraying is carried out in a partial enclosure, a work area or a spray space, then it should be fire separated from adjoining rooms.

The spray booth should be fitted with extraction ventilation, whose purpose is to:

- Draw overspray away from the operator
- Control flammable and hazardous vapours
- Collect vapours, droplets and solid particles
- Filter or wash the air before it is discharged

Ignition sources should be kept out of spraying areas at all times. Even when spraying is not taking place, flammable residues, contaminated materials, drying and cleaning operations may still present a fire risk.
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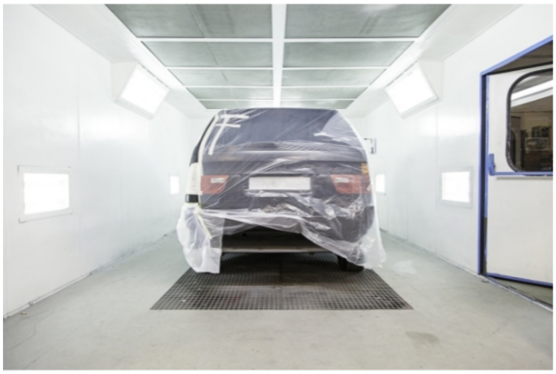


Spraying in the open air
In the past, it was not unusual for spraying, particularly of large items, to be carried out in the open air. This is less common now because better finishes can be achieved indoors, under controlled conditions, and there are also environmental restrictions. Occasionally, outdoor spraying may be unavoidable such as applying protective coatings to large structures. The precautions are like those outlined for workshops. All potential sources of ignition should be removed before spraying. The 'natural' ventilation should be checked to ensure it is adequate to disperse vapours.

Additional mechanical ventilation may be necessary if the spray area is in a 'sheltered' location or surrounded by walls and other structures.

Spraying should not be carried out near building openings or near pits, trenches, basements, etc. where flammable vapours could accumulate.

Disposal
Waste liquids will generally need to be stored and handled according to the same standards as the flammable liquids from which they were derived. Dispose of waste liquids safely, taking account of the need to prevent pollution. Never put waste liquid into public drains or watercourses. When in doubt, consult the local waste disposal authority.

Do not mix waste materials collected from different processes before disposal unless the various components are known to be compatible, and only after considering the eventual disposal technique to be used. Any drums used for waste materials should be sound and not contain any incompatible residues. If a drum is being used as a collecting station for waste liquids, use a funnel that fits securely into the drum opening to reduce the possibility of spillage. There are funnels with lids and flame arresters to stop any external ignition from flashing back into the drum or to prevent the drum becoming dangerously pressurised if it is engulfed by fire.

Waste containing drums should be appropriately labelled before being sent off site for disposal.

The dangers of electricity in hazardous areas

Hazardous area classification is the method used to identify areas where flammable concentrations of gases or vapours are likely to be present.

The concept of hazardous area classification has, in the past, been used solely as the basis for selecting fixed electrical apparatus. However, it also can be used to help eliminate potential ignition sources, including portable electrical equipment, vehicles, hot surfaces, etc. from flammable atmospheres.

There are three classes of hazardous area or zone: *zone 0, zone 1 and zone 2*. (These were discussed in detail earlier in 10.3)

Any electrical equipment that must be inside the spray area should be designed and constructed for use according to the hazardous area classification.

Precautions should also be taken to prevent vapours being ignited by the discharge of static electricity. Non-conducting footwear and clothing made of synthetic fibres can cause electrostatic sparks, especially if they are worn in areas with non-conducting floors. Electrostatic build-up may be reduced by using antistatic footwear and antistatic clothing and floors.

The transport of dangerous substances

Transportation of dangerous goods, whether by road or rail, carries with it a risk of traffic accidents. Accordingly, there is also the risk of an incident, such as spillage of the goods, leading to hazards such as fire, explosion, chemical burn, or environmental damage. Whilst many goods are not considered sufficiently dangerous to require special precautions during transportation some, however, have properties which make them potentially dangerous.

Dangerous goods have been tested and assessed against internationally agreed criteria (a process called classification) and found to be potentially dangerous (hazardous) when carried. They are assigned to the following different classes depending on their predominant hazard.

In the UK and Europe, the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2009 (CDGR) and the European agreement ("Accord européen relatif au transport international des marchandises dangereuses par route" - known as ADR) regulate the carriage of dangerous goods by road. There are nine classification types, with sub-divisions, as follows:

UN Class	Dangerous Goods	Division(s)	Classification
1	Explosives	1.1 - 1.6	
2	Gases	2.1	Flammable gas
		2.2	Non-flammable, non-toxic gas
		2.3	Toxic gas
3	Flammable liquid		Flammable liquid
4	Flammable solids	4.1	Flammable solid
		4.2	Spontaneously combustible substance
		4.3	Substance which in contact with water emits flammable gas
5	Oxidising substances	5.1	Oxidising substance
		5.2	Organic peroxide
6	Toxic substances	6.1	Toxic substance
		6.2	Infectious substance
7	Radioactive material		Radioactive material
8	Corrosive substances		Corrosive substances
9	Miscellaneous dangerous goods		Miscellaneous dangerous goods

Key safety principles in loading and unloading of tankers and tank containers

Road tankers are one of the most recognised means for the conveyance of products from manufacturers distribution terminals through to customers. A key function of a road tanker, aside from the safe conveyance of products, is the correct interfacing with a loading gantry/offloading point at a distribution terminal. This should ensure safe operation when loading and unloading.

Drivers of tankers must be made fully aware of the hazardous nature of the materials carried and the action that needs to be taken in the event of an emergency. The Transport Emergency card (TREM card) is a document which describes the nature of the hazardous load and action to be taken in an emergency. The TREM card must be kept in the vehicle cab so that it can be easily located by the emergency services in the event of an accident. There should be clear written procedures for the loading/unloading operation. If substances are flammable or explosive, earth connections should be used during loading and unloading to prevent the possibility of a static spark, and no other sources of ignition, such as smoking materials should be allowed in the vicinity.

The loading/unloading area should be in a separate area from other vehicles to avoid the possibility of collisions. If not, temporary barriers should be placed around the area until the operation is completed.

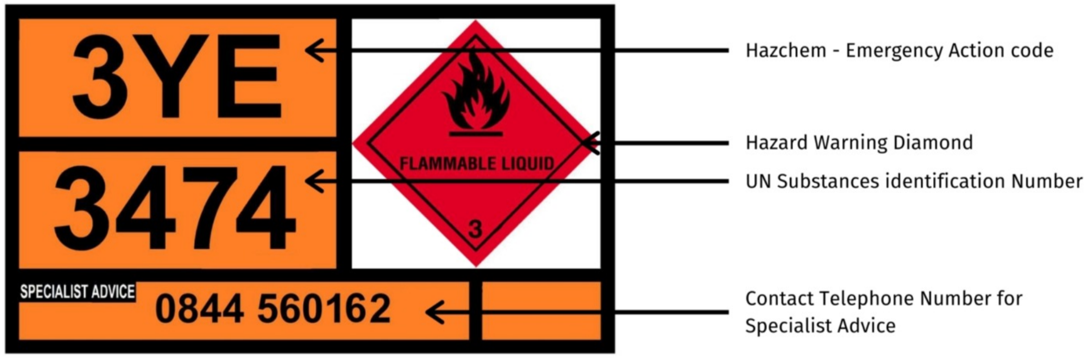
If top filling a tanker a working platform should be used, or handrails fitted to prevent the driver from falling.

Fire extinguishers should be carried on all vehicles. Spill kits should be available at the unloading/loading location.

Where bulk storage tanks are used for different substances, there is always the possibility of cross contamination - a substance being unloaded from a tanker into the wrong bulk tank at a distribution terminal. This can be prevented by strict operating procedures and the use of couplings of a different design for each substance. Conversely, care must be taken when loading tankers with different substances from those previously carried.

Labelling of vehicles and packaging of substances

Warning signs are used on vehicles to alert emergency services and other road users that a vehicle is carrying dangerous goods which pose a greater risk to people, property, and the environment than ordinary loads.



The signs are normally displayed on three sides of the vehicle. The information is used by the Emergency Services in the event of an accident or spillage.

The sign provides information on:

- Nature of the product.
- The fire extinguishing media to be used.
- Spillage containment or dilution.
- Whether the substance poses a threat to the Public.
- Emergency contact numbers.

When dangerous goods are transported in packages the package needs to be labelled and marked indicating the hazardous nature of the contents. Generally, this means at least a hazard warning diamond and UN number, preceded by the letters "UN" as in the example that follows.

Additionally, the packaging itself must be of a UN type-approved design. This means that it has been tested and certified and marked as such.

The importance of driver training programmes

In addition to holding a licence for the class of vehicle that they are driving, all drivers of vehicles carrying dangerous

goods must attend an approved basic training course (updated periodically) and sit an examination to demonstrate competency.

These courses equip drivers with information and tools so that they:

- Are aware of the hazards arising in the carriage of dangerous goods.
- Can take steps to reduce the likelihood of an incident taking place.
- Can take all necessary measures for their own safety and that of the public and the environment to limit the effects of any incident that does occur.
- Have individual practical experience of the actions they will need to take.

Drivers may receive additional training, such as Defensive Driving Training.

Hazardous environments

Resistance to mechanical damage, protection against solid bodies, objects and dusts, protection against liquids, wet and corrosive environments

The IP rating (published by the International Electro-technical Commission-IEC) is set out in standard IEC EN 60529 and rates electrical enclosures by the level of ingress protection against solids (1st digit) and against liquids (2nd digit). The higher number for each digit, the better the protection - refer to table below.

Protection against solids	IP		Protection against water
No protection	0	0	No protection
Solids > 50 mm	1	1	Vertically falling water
Solids > 12 mm	2	2	Vertically water – enclosure tilted 15°
Solids > 2.5 mm	3	3	Sprayed water 60° from vertical
Solids > 1.0 mm	4	4	Splashed water from all directions
Dust protected	5	5	Hosing jets from all directions
Dust tight	6	6	Strong hosing jets from all directions
		7	Temporary immersion: 1m for 30 minutes
		8	Immersion: manufacturer defined depth and time

Although the table uses simplified definitions such as "splashed water", IEC 60529 details exactly the test conditions and the requirements each level must meet. For IPX8 the machine manufacturer defines the immersion depth and time, in the case of Rotork valve IQ "IP68 depth 7 metres, 72 hours duration".

The NEMA - National Electrical Manufactures Association system of rating uses a scale between 1 (low protection) and 13, mixed for indoor and outdoor locations, different liquid and dust types, and corrosive agents and is therefore a more complex matrix. NEMA is recognised across North and South America including Canada and may also be specified in other parts of the world if a US based contractor or end user has specified the actuators. The table below shows a simplified version with the nearest equivalent IEC standard IP code.

The NEMA code also includes ratings for hazardous locations but these are rarely referred to, with other hazardous area classification systems being favoured.

NEMA	Abbreviated Protection Description	IP Equivalent
1	Indoor: Accidental contact and falling dirt	IP30
2	Indoor: Accidental contact, falling dirt and falling liquid/light splashing	IP31
3	Outdoor: Rain tight, dust tight and ice resistant (enclosure undamaged after ice has melted)	IP64
3.5	Outdoor: Rain tight, dust tight and ice proof (operable during icing)	IP64
4	Indoor/outdoor: watertight (hose down), dust tight and ice resistant	IP66
4X	Indoor/outdoor: watertight (hose down), dust tight, ice and corrosion resistant	IP66
6	Indoor/outdoor: Occasional submersion (6 ft/30min), dust tight, ice and corrosion resistant	IP67
7,8,9 & 10	Hazardous locations	N/A
12	Indoor: dust tight, dripping water, oil, and non-corrosive liquids	IP64
13	Indoor: dust tight, spraying water, oil, and non-corrosive liquids	IP65

In chemical plants, corrosion is present to some extent in practically all electrical installations. Some of this corrosion is of a limited nature and relatively harmless. In other cases, a more suitable material or a better appreciation of design factors would avoid severe cases which call for costly shutdowns. Numerous metals and alloys are available for electrical installations; all have advantages and disadvantages. This information, together with pertinent design factors, is the key to trouble free electrical units.

When specifying electrical products for harsh environments, choosing the right materials to ensure adequate corrosion-resistance is crucial. In offshore oil and gas operations, equipment is under constant exposure to seawater and salt spray, which are highly corrosive due to the action of sodium chloride and other dissolved chlorides.

Other corrosive substances such as hydrogen sulphide and carbon dioxide also occur naturally in oil and gas environments. Other corrosives that affect a wide range of industries include chlorine, bromine, hydrochloric acid, and ammonia.

Key steps to protecting equipment from corrosion are:

- Selecting materials according to their galvanic properties. Different metals and alloys have different electrode potentials. When two different metals are electrically connected in the presence of an electrolyte, such as seawater, the more active metal will become anodic - losing electrons and increasing its oxidation state in a process known as galvanic corrosion. Galvanic corrosion can be minimized by selecting metals close together in the galvanic series.
- Using protective coatings. Various finishes can be applied to help isolate metallic surfaces from the surrounding corrosive environment. The most familiar example is ordinary paint applied to steel to prevent rust, but there are many other methods including baked enamel, epoxy powder coat and PVC coating.
- Taking advantage of passivation. Certain metals form a layer of metal oxide on the surface, a few molecules thick, in a process known as passivation. This occurs naturally, but the process can also be enhanced through chemical passivation treatments or anodisation.
- Choosing non-metallic components. Manufacturers are increasingly offering non-metallic products that are completely impervious to the environments and substances that can corrode metals.

The classification of hazardous areas, zoning

Area classification is a method of analysing and classifying the environment where explosive gas atmospheres may occur. The main purpose is to facilitate the proper selection and installation of apparatus to be used safely in that environment, considering the properties of the flammable materials that will be present (*discussed in detail in 10.3*).

The use of permits-to-work

Work in industries where there may be flammable inventories present (such as an offshore oil and gas installation),

in particular maintenance work, must be strictly controlled. Such activities, which may involve the use of spark producing tools or open flames (such as welding) will usually require a hot work permit. The permit to work will form part of an organisations safe systems of work, to ensure that such work can be safely carried out.

The principles of pressurising and purging

The technique of pressurizing and purging enclosures of electrical apparatus is to prevent the ingress of a flammable atmosphere. Purging is a widely accepted protection concept for explosion protection. It is accepted world-wide (using European Standards, NFPA or IEC Standards) and is relatively straightforward to comprehend. Explosion protection is achieved by keeping the potentially explosive atmosphere away from any source of ignition (thermal or electrical). The potentially ignition capable apparatus is mounted inside an enclosure, the enclosure is then pressurized to a positive pressure relative to the atmospheric pressure (a positive pressure of 0.5 mbar is all that is required).

If this positive pressure is maintained, no gas (or even dust) will be able to enter the enclosure, hence the internal equipment cannot be exposed to a potentially explosive gas. There is however a chance that an explosive gas mixture may have entered the enclosure prior to the positive pressure being achieved. To ensure that the enclosure is pressurized with a non-explosive gas (i.e. Air or Nitrogen) the enclosure is 'purged' to flush out the existing contents and ensure that all areas of the enclosure contain only the purging gas. Purging can be used for equipment in Zone 1 or 2 areas.

Intrinsically safe equipment, flameproof equipment, type 'n' equipment, type 'e' equipment

Intrinsically safe (Ex i)

A type of protection in which the electrical equipment under normal or abnormal conditions is incapable of releasing sufficient electrical or thermal energy to cause ignition of a specific hazardous atmospheric mixture in its most easily ignitable concentrations. This type of protection is referred to as "Ex i".

Flame-proof (Ex d)

A type of protection in which an enclosure can withstand the pressure developed during an internal explosion of an explosive mixture and that prevents the transmission of the explosion to the explosive atmosphere surrounding the enclosure and that operates at such an external temperature that a surrounding explosive gas or vapour will not be ignited there. This type of protection is referred to as "Ex d".

Increased Safety (Ex e)
A type of protection in which various measures are applied to reduce the probability of excessive temperatures and the occurrence of arcs or sparks in the interior and on the external parts of electrical apparatus that do not produce them in normal service. Increased safety may be used with flame-proof type of protection. This type of protection is referred to as "Ex e".

Type n
A type of protection applied to electrical equipment such that in normal operation it is not capable of igniting a surrounding explosive atmosphere. This type of protection is referred to as "Ex n".

Emergency planning

The need for Emergency preparedness

Introduction
The potential for major industrial accidents, which has become more significant with the increasing production, storage and use of hazardous substances, has emphasised the need for a clearly defined and systematic approach to the control of such substances in order to protect workers, the public and the environment.

Both the ILO Convention C174 Prevention of Major Industrial Accidents (1993) and the ILO Code on the Prevention of Major Industrial Accidents (1991) express the need for emergency preparedness.

Section 8 of the ILO Code requires that "emergency plans must be in place for major hazard installations which cover the handling of emergencies both on site and off site". It goes on to state that for both on-site and off-site emergency planning, a scenario analysis should be based on those accidents which are more likely to occur, but other less likely events which would have severe consequences should also be considered.

The analysis should indicate:

- The worst events considered.
- The route to those worst events.
- The timescale to lesser events which might lead to the worst events.
- The size of lesser events if their development is halted.
- The relative likelihood of events.
- The consequences of each event.

Consequence minimisation via emergency procedures
Organizations are often required to have written emergency procedures in place in order to:

- Comply with national laws.
- Satisfy demands from their insurers, their regulatory agency, shareholders, stakeholders and unions.
- Protect staff, the public, the environment, the business, their property and their reputation.

Having a well defined and practiced emergency plan can ensure that organisations can have confidence that prompt action from well trained staff can minimise the impact of the incident in terms of casualties; damage to plant and equipment and harm to the environment. As an example, the consequences of the Piper Alpha north sea oil platform disaster in 1988 (167 deaths and complete destruction of the platform) may have been greatly reduced had an effective emergency response plan been in place.

First Aid/medical
The consequences of personal injury can be minimised by prompt treatment. In many countries, national laws require the appointment of first aiders in all workplaces. In higher risk workplaces (for example offshore oil and gas installation where, additionally, there is no easy access to hospitals) a higher level of medical treatment is provided in the form of paramedics or even doctors.
Fire and evacuation
Fire is a threat to most workplaces, and therefore fire and evacuation procedures will be common to most workplaces. In the event of a fire starting, the speed of detection, raising the alarm and dealing with the fire is crucial in minimising loss, with respect to personnel and property. Most organisations, in addition to ensuring that workers are aware of the fire procedures, will have staff trained in the use of fire extinguishers and fire marshals to aid evacuation. In larger, higher risk premises (such as an oil refinery) organisations often have their own fire departments to both help develop emergency plans and to lead the response in the event of a serious fire.
Spill containment
Generation and implementation of effective emergency response and spill control procedures are fundamental aspects of any effective health and safety management system. Again, national legislation may require spill procedures with respect to minimising the effects on the environment.
Such procedures may range from having drip trays or bunds around vessels on site, to having relevant spill containment equipment for off-site emergencies, such as contamination to water courses.
An emergency spill control procedure should include the following:

- Spills involving hazardous materials should first be contained to prevent spread of the material to other areas. This may involve the use of temporary dyking, sand bags, dry sand, earth or proprietary booms/absorbent pads.
- Wherever possible the material should be rendered safe by treating with appropriate chemicals to neutralise/stabilise.
- Hazardous materials in a fine dusty form should not be cleared up by dry brushing. Vacuum cleaners should be used in preference.
- Treated material should be absorbed onto inert carrier material to allow the material to be cleared up and removed to a safe place for disposal or further treatment as appropriate.
- Waste should not be allowed to accumulate. A regular and frequent waste removal procedure should be adopted.

Development and maintenance of emergency plans

Emergency planning is a legal requirement for some employers' establishments. In all cases where a major accident could occur, which could result in serious harm to people or the environment, proper planning will assist in minimising the consequences. Good planning will also optimise the use of resources.

The emergency plan should address the response required during every phase of the emergency, both the immediate needs and the longer term recovery. The first few hours after the accident occurs is the 'critical' phase of an accident response, when key decisions, which will greatly affect the success of any mitigation measures, must be made under considerable pressure and within a short period of time.

Therefore, a detailed understanding of the likely sequence of events and appropriate countermeasures will greatly benefit anyone who may reasonably be expected to have a role to play.

Emergency planning is part of an overall planning strategy for preventing and minimising the effects of major accidents to people and the environment. There are three basic parts of this major accident strategy (proposed by the UK Advisory Committee on Major Hazards.) They are:

- *Identification* - establishments holding more than specified quantities of dangerous substances should notify their presence to the local authority/enforcing authority.
- *Prevention and control* - appropriate controls based on an assessment of the hazards, risks and possible consequences, the likelihood of a major accident can be minimised.
- *Mitigation* - even with the best controls, major accidents will never be totally eliminated so the effects of any that do occur should be kept as small as possible. Emergency planning is one of the principal steps to achieving this.

It goes without saying that emergency plans should be kept up to date. If circumstances change (for example change of legislation, re-organisation) then the plans should be reviewed and updated as necessary.

On Site emergencies

The on-site plan should concentrate on those events identified as being most likely to occur. The level of planning should be proportional to the probability of the accident occurring. The plan should have the flexibility to allow it to be extended and increased to deal with extremely unlikely consequences which may arise through combinations of accidental circumstances and weather conditions.

The on-site plan should detail how the operator prepares people on the establishment for an emergency (people includes all those who may be on site at any time such as operatives, supervisors, managerial staff, non-production staff, contract workers and visitors), and how to control, contain and mitigate the effects of any emergency. The on-site plan should also detail how assistance from other organisations off site will be summoned, and how those who work on the establishment will assist any external organisations, including assisting with off-site mitigatory action.

In order to make the best use of available resources in the event of an emergency, and to avoid confusion, the on-site emergency plan should identify nominated key personnel (by name or by job title). It is recommended that the names and telephone numbers of authorised personnel are included in the annexes of the emergency plan, as this will facilitate updating changes.

The principal facility that should be considered in the on-site emergency plan is the on-site Emergency control centre (ECC), the place from which operations to manage the response to the emergency are directed and co-ordinated. This will normally be the location occupied by the site main controller, other key personnel as appropriate, and by the senior officers of the emergency services in attendance for tactical and operational command and control.

The onsite ECC should have good communication links with the site incident controller and all other installations on the establishment, as well as communication with appropriate points off site, which may be via the on-site emergency services. These links should include emergency services' headquarters, hospitals and the health authority, company headquarters, regulatory authorities and the media (to assist early distribution of public health and safety advice to minimise delay).

However, once an off-site ECC is set up, the media contact and enquiries will be via the off-site ECC media liaison representative. The on-site media contact is an interim measure.

The onsite ECC should have facilities to record the development of the incident to assist in its management and in decision making on the appropriate method of control.

Additional content of the plan should include:

- Name or position of the person with responsibility for the liaising with the local authority responsible for preparing the off-site emergency plan.
- A description of foreseeable conditions or events which could be significant in bringing about a major accident and controls to limit consequences.
- Arrangements for providing early warning of the incident, and actions to be taken.
- Arrangements for training staff.
- Equipment available that may be required to deal with an incident (such as firefighting equipment; spillage control equipment; damage repair equipment).
- Information such as site drawings; materials safety data sheets; inventories of materials. Arrangements for dealing with the media.

Off Site emergencies

The off-site emergency plan should be based around the major accident hazards which could affect people and the environment outside the boundary of the establishment, or which will require the attendance of emergency services from outside the establishment if an emergency arises.

The plan should concentrate on those events identified as being most likely to occur. The level of planning should be proportional to the probability of the accident occurring. The plan should have the flexibility to allow it to be extended and increased to deal with extremely unlikely consequences which may arise through combinations of accidental circumstances and weather conditions.

The off-site plan will normally be prepared by the local authority after discussing with the relevant organisation possible scenarios and emergencies that can arise from the establishment in question. The offsite plan will often be implemented when on site emergencies escalate. The liaison between the site operator and local authority during an onsite emergency is crucial.

The operator is required to provide the local authority with the necessary information about the nature, extent, and likely effects of reasonably foreseeable major accidents. The information should be sufficiently detailed to help prepare the off-site emergency plan. The local authority can request any additional, information that it may reasonably require for the preparation of the off-site emergency plan. Local authority emergency planning staff will produce plans in liaison with operators' staff, the competent authority, the emergency services, the health authority, and appropriate members of the public.

The emergency services have duties to deal with accidents and emergencies of all sorts. Therefore, the off-site emergency plan is principally a tool to co-ordinate the existing emergency services' plans, as far as possible, in their preparation for dealing with the specific hazards and risks associated with accidents on major hazard establishments. This includes identifying key personnel from a range of organisations and defining their duties in the event of an accident. It is then possible to ensure that those identified are adequately trained to carry out these roles.

Additional content of the plan should include:

- Arrangements for receiving early warnings and call out procedures.
- Arrangements for co-ordinating resources needed to implement the plan.
- Arrangements for mitigating action (for example, sheltering members of the public; controlling traffic; keeping people away from the affected area).
- Arrangements for communicating with and informing the public.

Post incident recovery

Post incident recovery can be made easier if some preparation is done beforehand.

Issues to consider include:

- Having off-site, current back-ups of critical data, vendor lists, employee details and other critical information. While this may be as simple as someone taking a disk home with him/her, it is important to recognize that if the disk or data is lost, the information may get into the wrong hands.
- Considering standby facilities/arrangements to minimise business disruption.
- Conducting an insurance review to ensure that your insurance is adequate to your needs. Ensure that insurance records are kept with back-up information.
- Communicating to the local community when the incident is over. Offering assistance to ensure safe return to their homes (may involve "clean up" for example).

Ongoing monitoring and maintenance of emergency plans

The emergency plans should be reviewed at regular intervals to ensure its continued suitability and effectiveness.

Reviews could also be initiated by:

- Changes in legislation.
- Advances in technology and equipment.
- Changes in organisational direction.
- Changes in products and activities.
- Lessons from incidents.
- Findings of audits, reporting and communication.

In addition, the plan should be tested regularly and revised as necessary. It should be updated when:

- Testing of the plan identifies shortcomings or omissions.
- Modifications or alterations occur at the facility.
- The type and quantities of hazardous materials on-site change significantly.
- An incident or near miss indicates the need to do so.
- Changes to surrounding land use impact upon the emergency plan.
- Changes occur that will impact on the execution of the plan, such as resources, safety systems, personnel and contact numbers.

The role of external emergency services and competent authorities in emergency planning and control

In many cases, organisations can handle local emergencies with their own resources (such as trained first aiders, training employees to use fire extinguishers, trained auxiliary fire fighters.) However, in the event of a major on site incident, additional resources may be required. Therefore, as part of the major emergency planning process, additional resource requirements must be considered.

This might involve:

- Liaison with the local fire brigades - ensuring that they are aware of nature the hazardous inventories that may exist on the premises.
- Carrying out periodic site familiarisation training for the local fire brigade officers.
- Conducting periodic desktop and practice emergency scenarios.
- Liaising with local medical facilities (hospitals). Ensuring that issues such as logistics arrangements in the event of multi casualties and treatment action for exposure to "special substances" are in place.

In the UK, under the Control of major accident hazard regulations (COMAH) major hazard sites (based on inventories of hazardous substances held on the site) are required to prepare, and submit to the relevant local authority, an off-site emergency plan. The local authority (in liaison with other agencies such as emergency services) are then charged with the responsibility of preparing for, and responding to, any off-site emergency.

The competent authority (HSE/Environment agency) acts as a "consultee" for the local authority and is responsible for ensuring that plans have been developed by the relevant local authority.

10.6: Work equipment and machinery maintenance

The hazards and control measures associated with the maintenance of work equipment and machinery

In this context, maintenance simply means keeping the workplace, its structures, equipment, machines, furniture and facilities operating safely, while also making sure that their condition does not decline. Regular maintenance can also prevent their sudden and unexpected failure.

There are **two main types** of maintenance:

- Preventive maintenance (including condition based) - periodic, scheduled checks and repairs.
- Corrective (or breakdown) maintenance - carrying out unforeseen repairs on workplace facilities or equipment after sudden breakage or failure. This is usually more hazardous than scheduled maintenance.

Maintenance-related accidents are a serious cause of concern. For example, analysis of data from recent years indicates that 25-30% of manufacturing industry fatalities in the UK were related to maintenance activity. Undertaking maintenance activities can potentially expose the workers involved (and others) to all sorts of hazards, but there are five issues that merit particular attention because of the severity of the harm that could be involved, and because they are commonly encountered during plant and building maintenance.

Disturbing asbestos
The health consequences of disturbing asbestos when drilling holes into the building fabric or replacing panels can be severe, as can the clean-up costs involved.

Falls from height
Maintenance work often involves using access equipment to reach roofs, gutters, building services, and raised sections of plant and machinery. It can be all too easy to fall from these positions, or to drop things onto people beneath.

Isolation and permits to work
Isolation and lock off arrangements, and in some cases permits to work, are essential to enable maintenance work to be conducted safely. If these are neglected or not implemented effectively, the consequences can be catastrophic.

Falls of heavy items
Heavy items sometimes have to be moved, or get disturbed, during maintenance work. If one of these falls, the results can be fatal. There may well be cranes, fork lift trucks or props available for use, but maintenance tasks can sometimes involve one-off situations and the handling of heavy loads isn't always properly planned.

Selection of contractors

You may do some or most of your plant and building maintenance in-house, but there will always be tasks that are too big or specialised and require contractors. To enable both in-house and contracted staff to work in safety you will need to properly brief them on your site and processes, and you will need them to follow safe working practices. Poor selection of maintenance contractors can have serious consequences when undertaking maintenance work. Steps should be taken to manage any risks arising from maintenance activity. Manufacturer's instructions should make recommendations on how to safely undertake maintenance of their work equipment and, unless there are good reasons otherwise, these should always be followed.

Where possible, equipment should normally be shut down and any residual/stored energy safely released (e.g. pneumatic pressure dumped, parts with gravitational/rotational energy stopped or brought to a safe position). For high-risk equipment, positive means of disconnecting the equipment from the energy source may be required (e.g. isolation), along with means to prevent inadvertent reconnection (e.g. by locking off). Formal systems of work, such as a permit to work, are required in some cases to safely manage high-risk maintenance operations.

In some cases, it may not be possible to avoid particular significant hazards during the maintenance of work equipment so appropriate measures should be taken to protect people and minimise the risk. These may include:

- Physical measures, e.g. providing temporary guarding, slow speed hold-to-run control devices, safe means of access, personal protective equipment, etc.
- Management issues, including safe systems of work, supervision, monitoring.
- Personnel competence (training, skill, awareness and knowledge of risk).

Work equipment may need to be constructed or adapted in a way that takes account of the risks associated with maintenance work. For example, lubrication and adjustment points can be repositioned/adapted to enable the work to be carried out at ground level; safe means of access can be provided on the equipment (e.g. handholds, anti-slip surfaces for feet).

Maintenance strategies

Planned preventative maintenance (PPM)
PPM, more commonly referred to as simply planned maintenance (PM) or scheduled maintenance, is any variety of scheduled maintenance to an object or item of equipment. Specifically, planned maintenance is a scheduled service visit carried out by a competent person, to ensure that an item of equipment is operating correctly and to therefore avoid any unscheduled breakdown and down time.

Planned maintenance comprises preventive maintenance, in which the maintenance event is pre-planned, and all future maintenance is pre-programmed. Planned maintenance is created for equipment based on factors such as manufacturers recommendation; legislation requirements; equipment criticality; running hours; the local operating environment. A good example of a planned maintenance program is car maintenance, where time and distance determine fluid change requirements.

Condition based maintenance (CBM)
CBM is a maintenance strategy that monitors the actual condition of the asset to decide what maintenance needs to be done. CBM dictates that maintenance should only be performed when certain indicators show signs of decreasing performance or upcoming failure.

Checking a piece of equipment/machinery for these indicators may include non-invasive measurements, visual inspection, performance data and scheduled tests (for example, vibration checks). Condition data can then be gathered at certain intervals, or continuously (as is done when a machine has internal sensors). Condition based maintenance is often applied to critical assets.

Unlike in planned scheduled maintenance (PM), where maintenance is performed based upon predefined scheduled intervals, condition based maintenance is performed only after a decrease in the condition of the equipment has been observed.

Breakdown maintenance (BM)
Is maintenance that is undertaken only when equipment fails. BM may be used when the equipment failure does not significantly affect the operation, production or generate any significant loss other than repair cost.

The factors to be considered in developing a planned maintenance programme

In order to ensure work equipment does not deteriorate to the extent that it may put people at risk, employers should keep such equipment 'maintained in an efficient state, in efficient order and in good repair'.

The frequency and nature of maintenance should be determined through risk assessment, taking full account of:

- Legal requirements (such as statutory inspection periods for cranes)
- Manufacturers' recommendations
- Frequency of use
- Age/condition of equipment
- Storage of spare parts
- Competence of maintenance staff
- Operating environment (such as operating in a corrosive/dusty/hot environment)
- Effects of failure on process or people
- Means of recording maintenance
- Insurers' requirements

Safety-critical parts of work equipment (such as pressure relief valves or fire/gas detectors) may need a higher and more frequent level of attention than other aspects, which can be reflected within any maintenance programme. Breakdown maintenance, undertaken only after faults or failures have occurred, will not be suitable where significant risk will arise from the continued use of the work equipment.

Inspection of work equipment

The purpose of an inspection is to identify whether work equipment can be operated, adjusted and maintained safely, with any deterioration detected and remedied before it results in a health and safety risk.

Not all work equipment needs formal inspection to ensure safety and, in many cases, a quick visual check before use will be sufficient. However, inspection is necessary for any equipment where significant risks to health and safety may arise from incorrect installation, reinstallation, deterioration or any other circumstances.

The need for inspection and inspection frequencies should be determined through risk assessment.

An inspection should concentrate on those safety-related parts which are necessary for the safe operation of work equipment and, in some cases, this may require testing or dismantling. However, not all safety-critical features on a particular item of work equipment may require inspection at the same intervals.

An inspection can vary in its extent, as the following demonstrate:

- Quick checks before use (e.g. electric cable condition on hand-held power tools, functional testing of brakes, lights on mobile machinery).
- Weekly checks (e.g. presence of guarding, function of safety devices, tyre pressures, and the condition of windows, mirrors and CCTV on mobile plant).
- More extensive examinations, undertaken every few months or longer (e.g. general condition of a ladder, close examination of a safety harness, portable appliance testing).

Equipment can be inspected by anyone who has sufficient knowledge and experience of it to enable them to know:

- What to look at
- What to look for
- What to do if they find a problem

The necessary level of competence will vary for inspections, according to the type of equipment and how and where it is used.

The use of *drones* for maintenance inspections is finding increased use in industry. For example:

- Inspection and surveying in the oil and gas industry.
- Surveying of hazardous/compromised areas.

As drones develop, they may become a useful health and safety tool, for example working at height inspections.

In 2019 OSHA was seen to be stepping up its use of drones to inspect worksites, with almost a dozen drone inspections carried out during the year.

Functionality testing of safety related parts of equipment

Functionality testing is carried out by simulating the environment in which the equipment is expected to operate. This is carried out in order to check, and correct, any issues associated with the functional operation of the equipment. Intervals for testing may be determined by considering issues such as manufacturers recommendations; legal requirements; operating environment.

Examples of equipment that may be functionality tested include:

- Smoke, fire detector systems
- Emergency shutdown valves
- Machinery interlock guards
- Heating, ventilation, air conditioning (HVAC) dampers

How Machinery is Safely Set, Cleaned and Maintained

Introduction
An effective maintenance programme will make plant and equipment more reliable. Fewer breakdowns will mean less dangerous contact with machinery is required, as well as having the cost benefits of better productivity and efficiency.

Additional hazards can occur when machinery becomes unreliable and develops faults. Maintenance allows these faults to be diagnosed early to manage any risks. However, maintenance needs to be correctly planned and carried out. Unsafe maintenance has caused many fatalities and serious injuries either during the maintenance or to those using the badly maintained or wrongly maintained/repaired equipment.

Procedures for Working at Unguarded Machinery – General
Whatever type of work is carried out, (such as cleaning or general maintenance) it should be subject to a detailed risk assessment, followed by the development of clear safe systems of work for carrying out the specific tasks (for example, when changing sharp blades on cutting machines, the system of work should include clear instructions on handling the blades, from removal to temporary storage, cleaning, and re-fitting).

The system(s) of work should lay down clear requirements for ensuring the competence of the persons charged with carrying out the specific tasks.

For work involving machinery cleaning or general maintenance, a Permit to work will usually be used to control the activities.

Setting up the Machine
This is the process of preparing the machine for operation or changing the operation of the machine (for example changing the cutter or the work piece on a lathe). This involves the person carrying out the operation with the guard removed. Potential hazards include poor access; handling sharp cutting tools; handling a heavy work piece and inadvertent starting of the machine. Guards should be replaced on completion of the task.

Cleaning and Maintenance
Cleaning and maintenance should only be carried out with the machine isolated from all sources of motive power (such as electrical, pneumatic, hydraulic) and with any stored energy released, as necessary. Any potential moving parts (such as fan blades, mixers) should be secured to prevent free movement.

How Machines are Isolated From all Energy Sources
Where maintenance requires that normal guarding be removed, or access is required inside existing guarding, then additional measures are needed to prevent danger from the mechanical, electrical, and other hazards that may be exposed. There should be clear company rules on what isolation procedures are required, and in what circumstances (for example, some cleaning of mixing machinery may require isolation, even though it might not be considered a maintenance task).

The basic rules, however, are that there should be isolation from the power source (usually, but not exclusively, electrical energy), the isolator should be locked in position (for example by a padlock), and a sign should be used to indicate that maintenance work is in progress. Isolation requires use of devices that are specifically designed for this purpose; not devices such as key-lockable emergency stops or other types of switches that may be fitted to the machine. Any stored energy (hydraulic or pneumatic power, for instance) should also be dissipated before the work starts.

If more than one maintenance worker is involved in the work, each of them should lock off the power with their own padlock. Multi-padlock hasps can be used in such circumstances. Such isolation procedures can also be applied to locking off valves for services (such as steam) and material supplies. The process is referred to as "Lock out tag out" (LOTO).

Before entering or working on the equipment it is essential that the effectiveness of the isolation is verified by a suitably competent person.

Typical causes of failure

Excessive stress
Excessive stress can be caused by factors such as:

- Stress raisers: Stress is concentrated in a localised area of an object. An object is strongest when force is evenly distributed over its area, so a reduction in area, e.g. caused by a crack, results in a localised increase in stress. A material can fail, via a propagating crack, when a concentrated stress exceeds the material's theoretical cohesive strength.
- Poor maintenance: such as unevenly tightening flanges on pipe work.

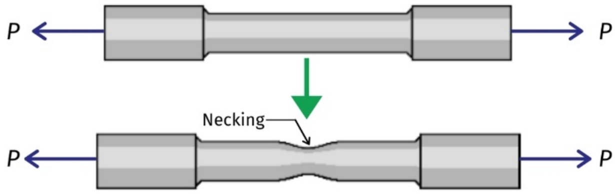
Abnormal external loading
Equipment may be externally loaded by loads carried on accessories such as lugs, supports, brackets, hangers, stairs, or ladders. Movement of foundations can also cause external loading, as can failure to consider thermal expansion pipe work passing through concrete walls. Wind can also create significant external loads.

Every structure needs to support a load. The total load is the sum of the static and dynamic loads. The static load is the effect of gravity on a structure. The dynamic load is the forces that move or change while acting on the structure. It is called "dynamic" because these forces change their magnitude, direction, and point and plane of application over time. The figure below shows the dynamic forces of the truck moving over the bridge and the wind on the bridge.

Metal Fatigue
Metal fatigue is the process by which a material is slowly damaged by stresses and strains that are less than those needed to cause the material to fail. For example, a steel wire might be used to suspend weights that are less than the amount needed to cause the wire to break apart (its tensile strength). Over time, however, those weights might slowly cause defects to develop in the steel. At some point, these defects may become so great that the steel wire breaks apart even though its tensile strength had never been exceeded.

The amount of stress or strain needed to bring about metal fatigue in a material depends on several factors. First is the material itself. In general, the fatigue limit of many materials tends to be about one quarter to three quarters of the tensile strength of the material itself. Another factor is the magnitude of the stress or strain exerted on the material. The greater the stress or strain, the sooner metal fatigue is likely to occur. Finally, environmental factors are involved in metal fatigue. A piece of metal submerged in a saltwater solution, for example, is likely to exhibit metal fatigue sooner than the same piece of metal tested in air.

Ductile Failure
In ductile fracture, extensive plastic deformation (necking) takes place before a fracture. The terms rupture or ductile rupture describe the ultimate failure of ductile materials loaded in tension. Rather than cracking, the material "pulls apart," generally leaving a rough surface.



Brittle fracture
Is a rapid run of cracks through a stressed material. The cracks usually travel so fast that you cannot tell when the material is about to break. There is very little plastic deformation before failure occurs. In most cases, this is the worst type of fracture because you cannot repair visible damage in a part or structure before it breaks.

The factors that may promote brittle failure include:

- High tensile stresses
- Residual manufacturing stresses
- Shock loading
- Low and high temperatures
- Weld defects
- Inappropriate use of brittle materials
- Operating outside the "safe operating envelope"

Buckling
Buckling is characterised by a sudden failure of a structural member subjected to high compressive stress. As an applied load is increased on a member, such as a column, it will ultimately become large enough to cause the member to become unstable and is said to have buckled.

Corrosive failure

There are several corrosion mechanisms that can affect equipment, they include:

General corrosion:
When a metal is immersed into an electrolyte, the surface immediately develops millions of microscopic and sub microscopic anodic and cathodic sites. The polarity of an individual site depends on a variety of factors, such as chemical composition, amount of residual stress and microstructure. In general corrosion, the anodic site corrodes,

but then develops a protective film that essentially protects the site from further corrosion. In effect, this causes the site to reverse polarity, or become more electrochemically noble than the surrounding sites. In turn, those sites corrode, but immediately develop a protective film. This continuous polarity reversal results in uniform deterioration of the entire exposed surface.



Galvanic corrosion:
When two dissimilar metals are electrically connected and placed into an electrolyte, the more electrochemically active metal will undergo corrosion at an increased rate, while the more noble metal will be protected to some degree by electrochemical means. It is important to note that moisture from medium to high humidity environments alone can serve as the electrolyte; therefore, components may experience galvanic corrosion even if they are not subjected to immersion conditions. Various factors will affect the galvanic corrosion rate in an electrochemical cell, including relative potentials of the dissimilar metals, relative exposed areas of the anode and cathode, electrolyte conductivity, and the polarization tendencies of the metals in the cell.

However, prudent design can easily minimize the likelihood of galvanic corrosion in most applications. Selection of appropriate materials, which are relatively close in electrochemical potential, can produce little or no tendency for galvanic corrosion to occur.

Stress corrosion cracking:
SCC is a process involving the initiation of cracks and their propagation, possibly up to complete failure of a component, due to the combined action of tensile mechanical loading and a corrosive medium. Indeed, it is the presence of tensile stresses that is dangerous, compressive stresses exerting a protective influence.

SCC can lead to unexpected sudden failure of metals subjected to a tensile stress, especially at elevated temperature in the case of metals. SCC is highly chemically specific in that certain alloys are likely to undergo SCC only when exposed to a small number of chemical environments.

Examples include mild steel and alkaline environments, Copper in Ammonia solutions. The chemical environment that causes SCC for a given alloy is often one which is only mildly corrosive to the metal otherwise.

The advantages and disadvantages of non-destructive testing (NDT)

NDT is the process of examining a material for defects (such as surface or sub-surface cracks, without damaging the material. Several methods are available. For example, visual; dye penetrant and magnetic particle (MPI) are methods for checking for surface cracks. Radiography, ultrasonic and eddy current methods can determine sub surface defects.

All methods have advantages and disadvantages. These are considered below:

Radiography

Advantages:

- Provides permanent record on film
- Technique standardized
- Reference standards available

Disadvantages:

- Trained technician needed
- Radiation hazards
- High cost of equipment (x ray)

Ultrasonic testing

Advantages:

- Safe to use
- Fast method
- Results available immediately

Disadvantages:

- Entirely dependent on operator skill
- Unsuitable for welding of complex shape or configuration
- Requires surface contact
- Surface must be clean and smooth

Magnetic particle testing:

Advantages:

- Simple to use and interpret
- Portable and relatively inexpensive

Disadvantages:

- Material must be ferro magnetic
- Demagnetization may be needed
- Power source required

Dye penetrant testing

Advantages:

- Simple to use and interpret
- Relatively inexpensive
- Portable and require no elaborate equipment
- Works on all materials

Disadvantages:

- Surface must be clean and dry
- Rust or paint will mask defects

10.7: Work Equipment

Why risk assessments must be carried out on work equipment

The selection of suitable work equipment for tasks and processes makes it possible to reduce or eliminate many risks to the health and safety of people at the workplace. This applies both to the normal use of the equipment as well as to other operations such as maintenance.

Equipment must be suitable, by design, construction, or adaptation, for the actual work it is provided to do. This means in practice that when you provide work equipment you should ensure that it is suitable for the work to be undertaken and that it is used in accordance with the manufacturer's specifications and instructions. If work equipment is adapted, it must still be suitable for its intended purpose. (For example, a counterbalanced forklift truck is purchased to lift palletised products from vehicles and store them in a warehouse, has a maximum SWL of 3 tonnes. If the truck later is required to lift people, for access, any cage adaptor fitted to the forks should be properly agreed and fitted by the truck manufacturer).

The location in which the work equipment is to be used needs to be considered and to take account of any risks that may arise from the circumstances. Such factors can invalidate the use of work equipment in a particular place. For example, a small wheel-based counter balanced forklift truck used in a warehouse would not be suitable for the rough terrain of a construction site.

Finally, the purpose for which the equipment is to be used should be considered. Unless properly designed, as above, forklift trucks should not be used for personal access; knives with unprotected blades are often used for cutting operations, where scissors or other cutting tools could be used, reducing the risk of cuts.

The means by which all forms of energy used or produced, and all substances used or produced can be supplied and/or removed in a safe manner

The most common sources of energy are power, heat and pressure but depending on the particular type of equipment there may be others that will need to be taken into account when carrying out a risk assessment.

Isolation means establishing a break in the energy supply in a secure manner, i.e. by ensuring that inadvertent reconnection is not possible. Employers should identify the possibilities and risks of reconnection as part of your risk assessment, which should then establish how secure isolation can be achieved. For some equipment, this can be done by simply removing the plug from the electrical supply socket. For other equipment, an isolating switch or valve may have to be locked in the off or closed position to avoid unsafe reconnection. The closed position is not always the safe position: for example, drain or vent outlets may need to be secured in the open position.

Work equipment itself can sometimes cause risks to health and safety in particular locations which would otherwise be safe. An example is a petrol engine generator discharging exhaust fumes into a confined space.

Exhaust gases from mobile work equipment with a combustion engine contributes significantly to airborne pollution in workplaces. For example, in motor vehicle workshops, underground car parks, in buildings where lift trucks are used and in tunnels. In such circumstances, a high standard of ventilation and/or extraction is needed to dilute toxic combustion products (such as carbon monoxide, carbon dioxide and oxides of nitrogen) to an acceptable level.

Combustion products can be harmful to health if there is not enough fresh air for people to breathe.

Ergonomic, anthropometric and human reliability considerations in use of work equipment

Ergonomic considerations

Ergonomics is concerned with the "fit" between the user, equipment, and their environments. It takes account of the user's capabilities and limitations in seeking to ensure that tasks, functions, information, and the environment suit each user.

Ergonomists and designers consider a wide range of human factors and consider biological, physical, and psychological characteristics as well as the needs of people - how they see, hear, understand, make decisions, and take action. They also consider individual differences including those that occur due to age, fitness/health, or disability and how these may alter peoples' responses and behaviours.

Anatomy	
Anthropometry	Dimensions of the body (static and dynamic)
Biomechanics	Application of forces by gravity and muscles
Physiology	
Work physiology	Expenditure of energy
Environmental physiology	Effects on humans of the physical environment
Psychology	
Skill psychology	Information processing and decision-making
Occupational psychology	Training, motivation, individual differences, stress

In order to address ergonomics issues at workplaces, Ergonomists interact and consult with designers, engineers, managers and the end users of any system, the workforce and individual workers.

When analysing work and how it can be improved from an ergonomics point of view there are five elements that need to be addressed:

- **The worker:** the human element of the workplace. Employees have a range of characteristics that need to be considered including physical and cognitive capacities; experience and skills; education and training; age; sex; personality; health; residual disabilities.
- **Job/task design:** what the employee is required to do and what they do. It includes job content; work demands; restrictions and time requirements such as deadlines; individuals' control over workload including decision latitude, working with other employees; and responsibilities of the job.
- **Work environment:** the buildings, work areas and spaces; lighting, noise, the thermal environment.
- **Equipment design:** the hardware of the workplace. It is part of ergonomics that most people recognise and includes electronic and mobile equipment, protective clothing, furniture, and tools.
- **Work organisation:** the broader context of the organisation, the work and how this affects individuals. It includes patterns of work; peaks and troughs in workload, shift work; consultation; inefficiencies or organisational difficulties; rest and work breaks; teamwork; how the work is organised and why; the workplace culture; as well as the broader economic and social influences.

"**Human error**" is a term often used to describe the cause of an accident. Human error has been defined as an inappropriate or undesirable human decision or behaviour that reduces, or has the potential for reducing effectiveness, safety, or system performance. Ergonomics applied to system design will make the system "error tolerant" by considering the cognitive capacity of the human to make decisions in several situations.

Anthropometric considerations

From an ergonomics viewpoint, appropriate design needs to cater for the range of humans at work. To do this, Ergonomists utilise anthropometric data. Anthropometry refers to the dimensions of the human body and how these are measured. It covers the size of people; their height and circumference; their weight and percentage body fat; the length and range of movement of their limbs, head, and trunk; and their muscle strength.

Measurements of large numbers of people are needed in any given population to determine ranges, averages, and percentiles. Children of different ages, male and female adults, and older people all may be included in the population sample depending on how the data may be used.

In workplace and equipment design, ranges of dimensions are often specified to allow for the short and the tall, the fat and the thin and those who may be differently proportioned to the average.

Ranges can include extremes at either end such the 5th percentile in height represents people who are in the shortest 5%, while the 95th percentile represents the tallest 5%.

Often a design needs to suit most of the population as far as possible while not accommodating everyone in the extremes of range. For example, seats in a bus or an aero plane suit 90% of the population adequately but may be very uncomfortable for very short or tall or obese people. In these cases, static dimensions are used as a guide e.g. average (mean) height of the travelling population.

Ninety-five percent of the population can be accommodated with some flexibility in design or by using adjustments e.g. desks and chairs. It may be very difficult to achieve a fit for very tall/short or big/small people above 97.5th percentile or below 2.5th percentile.

Ergonomic designed work equipment examples

Case Study 1

Crimper Tool

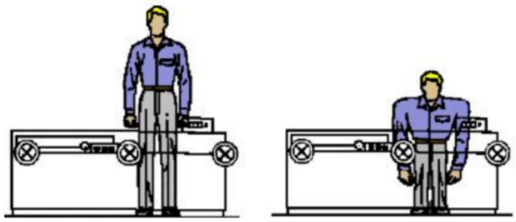
Developing an ergonomically sound manual wire crimping tool is a significant challenge due to the combination of high manual force application and repetitive task frequency. However, clear strides have been made to reduce injury risk while increasing user satisfaction and performance.

An analysis of leading brand-name tools against fundamental ergonomic principles identified several effective design features in the critical areas of strength, clearance, posture, and reach.

Overall, the Pressmaster K67 demonstrated the best combination of ergonomic features by incorporating both mechanical solutions and user-centred design techniques, resulting in efficiency, comfort, and ease-of-use.

Case Study 2
The Cranfield man

The study of ergonomics really took off in the post war period with the Cranfield Institute of Technology at Cranfield University, UK. They looked at a lathe and worked out what the ideal body shape was for its operator where they can comfortably reach all the controls. They termed this human "Cranfield Man". Cranfield man was 1.35m tall, with shoulder width of 0.61m and arm span of 2.44m!



Trying to recruit people with these rather strange characteristics was clearly not a good solution! The ergonomics approach, redesigning the machine tool to suit real people, was clearly more effective.

The layout and operation of controls and emergency controls

Work often requires the use of human-machine interaction, where:

- The machine displays information to the operator.
- The operator uses control actuators to affect the machine (switches various functions of machine on and off).
- The machine in turn provides feedback to the operator.

To ensure accurate and efficient use of the machine, and as required under International Standards (such as EN 894-1: 1997 and ILO CoP Safety and health in the use of machinery).

Both the control actuators and the displays must be designed with consideration of issues such as:

- Suitability for the task - including function allocation, complexity, grouping, identification, operational relationship.
- Self descriptiveness - including information availability.
- Controllability - including redundancy, accessibility, movement space.
- Conformity with user expectations - including compatibility with learning and practice and with consistency.
- Error tolerances - including error correction, error handling time.
- Suitability for individualisation and learning - including flexibility.

Equipment control devices should be clearly visible and identifiable, and distinguishable from one another by their separation, size, shape, colours or feel and labelled to identify their function (for examples, the ability to clearly identify "start", "stop" and "emergency stop" controls).

Start controls
Machinery should be fitted with a specific start control device (usually green in colour). It should be possible to start machinery only by voluntary activation of the control device provided for that purpose. Near each start control there should be a stop control (usually red in colour). For machinery functioning in automatic mode, the starting of the machinery, restarting after a stoppage, or a change in operating conditions, may be possible without intervention, provided this does not lead to a hazardous situation.

Stop controls
Machinery should be fitted with a reliable control device allowing the machinery to be brought safely to a complete stop. The machinery's stop control should have priority over the start controls.

Emergency stop
Where it is appropriate to have one, based on the risk assessment, an emergency stop should be provided at every control point and at other appropriate locations around the equipment so that action can be taken quickly. Emergency stops are provided to enable a rapid response to potentially dangerous situations, they should not be used to stop the equipment during normal operation.
If emergency stop controls are considered necessary, they should be easy to reach and easy to use.

Reducing the need for access
Reducing the need for a worker to access the hazard zone, by good design, reduces the risk. Examples of how this may be done include:

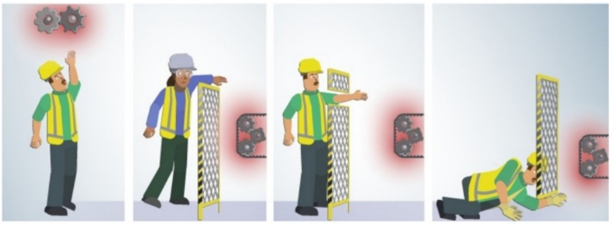
- Automation of the process.
- Operating remote control system outside danger zones.
- Extending lubrication points outside the danger zone.

When operator access is required to the hazard zone (for example, to set up a machine), "inching/jogging" buttons can reduce the risk, by providing "slow operation" during set up.

The importance of size of openings, height of barriers; and distance from danger
When considering the use of fixed guarding to safeguard machinery, it is important to consider the size of openings of the guard (as in for example, mesh guards); the height of the guards (as in fixed perimeter guarding) and the distance of the guard from the danger.

BS EN ISO 13857 details safe distance requirements for guarding, to prevent access by limbs to danger zones.

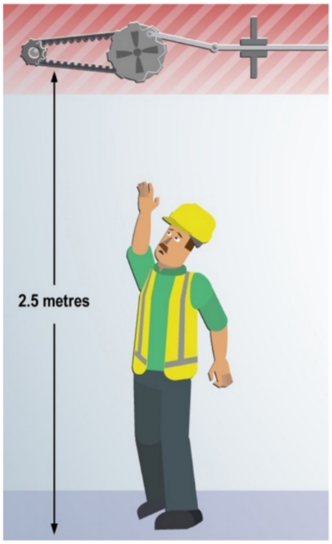
The safe distances have been derived based on the following:



Access by reaching upwards
The safety distance determined between the ground, the catwalk or the permanent working platform and the bottom of the danger zone is a function of the height of the danger zone and its expected accessibility.

Any danger zone located less than 2.5 m from the ground, catwalk or permanent working platform must be made inaccessible by a guard or by a protective device.

Any danger zone located more than 2.5 m from the ground, catwalk or permanent working platform must be made inaccessible by a guard or by a protective device if its access can be foreseen (for example, a worker doing regular preventive maintenance by using an elevating platform in or near the danger zone).



Access by reaching over protective structures
The following symbols are used to designate the critical dimensions relating to access from above the guard:

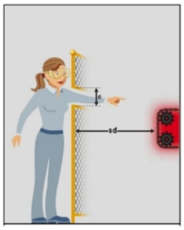
- « a » is the height of the danger zone in relation to the ground or working platform.
- « b » is the height of the guard.
- « c » is the horizontal distance between the guard and the danger zone.

As a general rule, a distance guard that protects a danger zone must be a minimum of 1800 mm high.

Detailed values for a, b and c can be found in tables within BS EN ISO 13857.

Access by reaching through an opening in a guard
The safety distance determined between the danger zone and the guard in the case of access through the guard is a function of the dimension and shape of the opening. The following symbols are used:

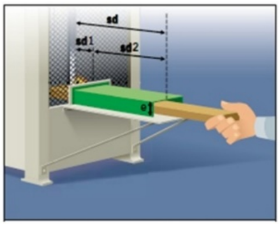
- « sd » is the safety distance, namely the distance between the guard and the danger zone.
- « e » is the smallest dimension of the opening.



Access by reaching through a guard
Again, tables in BS EN ISO 13857 give the maximum acceptable opening (shape and dimensions) in relation to the chosen safety distance "sd".

Tunnel guards
A guard in the form of a tunnel allows the material or the worked part to pass through while preventing the worker from accessing the danger zone. In this case, the safety distance "sd" is the distance of the tunnel from the danger zone "sd1" plus the length of the tunnel "sd2".

The safety distance "sd" therefore depends on the tunnel's shape and "e" dimensions.
Again, tables in BS EN ISO 13857 are used to determine "e" in relation to "sd", or "sd" in relation to "e".

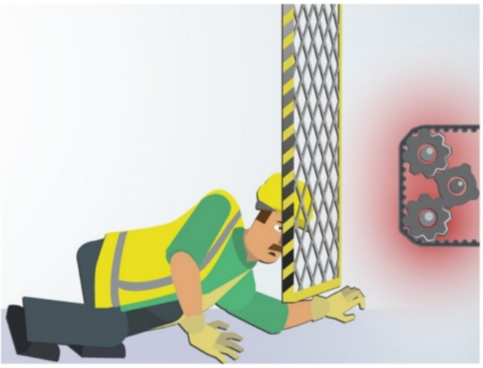


Limiting movement
Free movement of the upper limbs (arms, hands, fingers) can also be limited in space by placing additional elements (such as a chicane) between the fixed guard and the danger zone.


Access by reaching under a guard

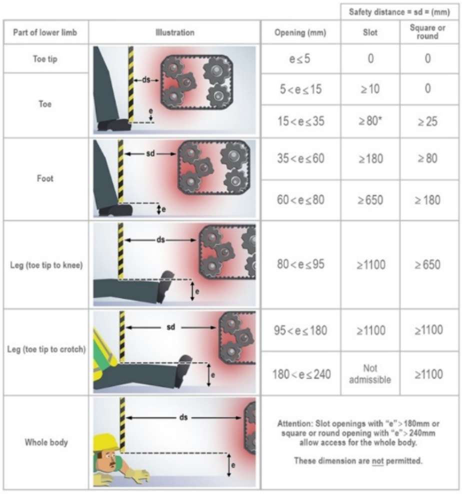
There may be several reasons for not extending the fixed distance guard to the ground: easier cleaning and recovery of parts on the ground, cost, for example.

The existence of this gap between the ground and the guard must be taken into consideration in risk assessment in order to determine the safety distance between the danger zone and the guard in the case of access from below the guard.



If the risk assessment determines that there is a risk of access to the danger zone by reaching under the guard for the lower and upper limbs, the minimum safety distance "sd" for an opening of given dimensions must be the longest safety distance appearing in the figure below.

The opening’s "e" dimension corresponds to one side of a square-shaped opening, to the diameter of a circular opening, and to the smallest dimension of a slot-shaped opening.



Part of lower limb	Illustration	Opening (mm)	Safety distance = sd = (mm) Slot	Square or round
Toe tip		e≤5	0	0
Toe		5<e≤15	≥10	0
		15<e≤35	≥80*	≥25
Foot		35<e≤60	≥180	≥80
		60<e≤80	≥650	≥180
Leg (toe tip to knee)		80<e≤95	≥1100	≥650
Leg (toe tip to crotch)		95<e≤180	≥1100	≥1100
		180<e≤240	Not admissible	≥1100
Whole body		Attention: Slot openings with "e">180mm or square or round opening with "e">240mm allow access for the whole body. These dimension are not permitted.		

Risks associated with initial integrity, location, and purpose of use

The selection of suitable work equipment for tasks and processes makes it possible to reduce or eliminate many risks to the health and safety of people at the workplace. This applies both to the normal use of the equipment as well as to other operations such as maintenance.

Equipment must be suitable, by design, construction, or adaptation, for the actual work it is provided to do. This means in practice that when you provide work equipment you should ensure that it is suitable for the work to be undertaken and that it is used in accordance with the manufacturer's specifications and instructions. If work equipment is adapted, it must still be suitable for its intended purpose. (For example, a counterbalanced forklift truck is purchased to lift palletised products from vehicles and store them in a warehouse, has a maximum SWL of 3 tonnes. If the truck later is required to lift people, for access, any cage adaptor fitted to the forks should be properly agreed and fitted by the truck manufacturer).

The location in which the work equipment is to be used needs to be considered and to take account of any risks that may arise from the circumstances. Such factors can invalidate the use of work equipment in a particular place. For example, a small wheel-based counter balanced forklift truck used in a warehouse would not be suitable for the rough terrain of a construction site.

Finally, the purpose for which the equipment is to be used should be considered. Unless properly designed, as above, forklift trucks should not be used for personal access; knives with unprotected blades are often used for cutting operations, where scissors or other cutting tools could be used, reducing the risk of cuts.

Work equipment risks associated with incorrect installation or re-installation; deterioration; or exceptional circumstances

When work equipment is first installed, and when it is moved or relocated, it must be inspected to make sure that it has been correctly installed and is operating safely. Where it is possible that the equipment is exposed to conditions that could cause it to deteriorate, it must be inspected regularly. Inspections should be recorded. Failure to inspect can lead to significant risks.

Examples include:

- Tower crane: on installation or relocation. Defective installation can lead to collapse.
- Pressure relief valves: Failure to install correctly can lead to overpressure explosion.
- Light sensors on guillotines: Where preventing access to a danger zone is dependent of effective installation.
- Equipment in a harsh environment: Corrosion may be accelerated in coastal areas.
- Extended use of equipment: may lead to failure if inspections not increased (exceptional circumstances).

The risk control hierarchy relating to work equipment

Controlling risks associated with work equipment involves the application of the following control hierarchy:

- Design out the risk (i.e. intrinsic safety)
- Introduce physical controls (i.e. hardware such as machine guards)
- Software measures (i.e. safe systems of work; information, instruction, and training)

Design to eliminate or minimise the risk
BS EN ISO 12100:2010 (Safety of machinery) states that: "Inherently safe design measures are the first and most important step in the risk reduction process… Inherently safe design measures are achieved by avoiding hazards or reducing risks by a suitable choice of design features of the machine itself…"

It is therefore at the equipment design step that the worker's safety is ensured. The designer tries to improve the equipment's characteristics.

For example:

- Creating a gap between the moving components on a machine to eliminate the trapping zones.
- Eliminating sharp edges on a piece of equipment.
- Limiting the drawing-in forces or limiting the energy levels (mass, velocity, acceleration) of the moving components of equipment.
- Positioning air conditioners in a building at ground level, to having to work at height to maintain them.
- Installing roll over protection systems (ROPS) on rough terrain vehicles such as dumper trucks.
- Installing lighting systems on sliding racks, minimising fall from height risks.



Physical (hardware) controls
Guards, whether they are fixed, interlocking or other types of guard, rank just below inherently safe design in terms of effectiveness in the hierarchy of risk reduction measures. Protective devices and electro-sensitive protective devices come next, such as safety light curtains, pressure mats, surface detectors or two-hand controls, followed by protective appliances such as push sticks or jigs to hold or manipulate the work piece.

Software measures
Safe work procedures, warnings signs and personal protective equipment are not considered as being the most effective means. Although essential in situations where no other solution seems to provide satisfactory results, their effects on safety improvement are considered less significant. They are often used with other risk reduction methods.

In all cases where the hazard cannot be eliminated, workers must receive training so that they are informed about the nature of the residual risk to which they are exposed and the means that are used for reducing this risk. This training is in addition to the general training that the employer must provide to the workers for the purpose of using equipment.

The training required will be proportional to the level of risk associated with the particular equipment.

Pressure systems

Definition of a Pressure system

According to the UK HSE Pressure system means:

"*a system comprising one or more pressure vessels of rigid construction; any associated pipe work and protective devices; the pipe work with its protective devices to which a transportable pressure receptacle is, or is intended to be, connected; or a pipeline and its protective devices, which contains or is liable to contain a relevant fluid*, but does not include a transportable pressure receptacle*."

(*includes steam, gases under pressure, and fluids that are artificially kept under pressure and become gases on release into the atmosphere).

Examples of pressure systems include:

- Boilers and steam heating systems
- Pressurised process plant and piping
- Compressed air systems (fixed and portable)
- Pressure cookers, autoclaves and retorts
- Heat exchangers and refrigeration plant
- Valves, steam traps and filters
- Pipe work and hoses
- Pressure gauges and level indicators

Types of inspection, frequencies and the statutory basis for examination of pressure systems

The UK Pressure Safety Systems Regulations 2000 require that all pressure vessels and associated pipe work must be

assessed initially to determine the appropriate regime of regular inspection and testing, this is called the "written scheme of examination".

Thereafter arrangements must be made for this inspection and testing to be undertaken at the correct intervals, by a competent person.

The nature of the examination should be specified in the written scheme. This may vary from out-of-service examination with the system stripped down, to in-service examination with the system running under normal operating conditions. Some systems (for example fired equipment) may need to undergo both out-of-service and in-service examinations. Where the written scheme requires both an out-of-service and an in-service examination, the in-service examination should be completed as soon as reasonably practicable after the completion of the out-of-service examination. The competent person may need to seek advice from the manufacturer/supplier on appropriate methods of testing, particularly where internal examination is difficult.

First examination
Where appropriate, the requirement for an examination before the system is first taken into use should be specified in the written scheme of examination. For equipment supplied in accordance with pressure systems regulatory requirements, the person who draws up or certifies the written scheme should consider whether an initial examination is appropriate and the form that any such examination should take. This consideration should take account of the results of the conformity assessment to which the equipment was subject before it was placed on the market. In general, further assessment of the equipment under the written scheme should be judged on the merits of each individual case.

Periodicity
When deciding on the periodicity between examinations, the aim should be to ensure that sufficient examinations are carried out to identify at an early stage any deterioration or malfunction which is likely to affect the safe operation of the system. Different parts of the system may be examined at different intervals, depending on the degree of risk associated with each part.

Protective devices (such as pressure relief valves) should be examined at least at the same time and frequency as the plant to which they are fitted. Some protective devices may need to be examined at more frequent intervals. The

examination should include checks that the devices function correctly and are properly calibrated or, alternatively, that they have been replaced by recently tested units.

All relevant factors should be considered when deciding on the appropriate interval between examinations.

Including:

- The safety record and previous history of the system.
- Any generic information available about the particular type of system.
- Its current condition, e.g. due to corrosion/erosion etc. (internal and external).
- The expected operating conditions (especially any particularly arduous conditions).
- The quality of fluids used in the system.
- The standard of technical supervision, operation, maintenance and inspection in the user's/owner's organisation.
- The applicability of any on-stream monitoring.

Prevention and testing strategy

Design and construction

Consideration should be given to:

- The expected working life (the design life) of the system.
- The properties of the contained fluid.
- All extreme operating conditions including start-up, shutdown and reasonably foreseeable fault or emergency conditions.
- The need for system examination to ensure continued integrity throughout its design life.
- Any foreseeable changes to the design conditions.
- Conditions for standby operation.
- Protection against system failure, using suitable measuring, control, and protective devices as appropriate.
- Suitable materials for each component part; the external forces expected to be exerted on the system including thermal loads and wind loading.
- Safe access for operation, maintenance, and examination, including the fitting of access (e.g. a door) safety devices or suitable guards, as appropriate.

Properties of the fluid

The system should be designed to avoid as far as possible the accumulation of liquids, condensates, or sediment in pipe work. For example, the design of a compressed air system or of steam pipe work should minimise the number of places, such as low points, where liquid can accumulate and should provide for adequate drainage. Devices should be fitted at appropriate points in the system to allow venting of vapour and/or to prevent a vacuum forming. All pipe work drainage should be to a safe place.

Extreme operating conditions

Account should be taken of the most demanding combination of temperature, pressure, and other relevant parameters to which the equipment may be subjected under reasonably foreseeable circumstances. These should include the conditions which will exist during start-up, shutdown, and standby operation.

Examination requirements

Vessels should be provided with suitably sized openings, including manholes and hand-holes where appropriate, to

allow adequate examination of the interior. Where internal examination may be unnecessary or even harmful, for instance because of size or the hazardous nature of the fluid contained within the system, the designer should consider what examinations are needed and provide adequate means for this to be carried out.

Foreseeable changes
These may include allowances for corrosion if some corrosion is foreseeable and unavoidable, or for wear if stirrers or agitators are liable to cause wear which may give rise to danger. The designer should ensure that the system can safely withstand the consequences of any reasonably foreseeable fault or emergency conditions unless it is to be fitted with appropriate control and protective equipment which will either prevent the conditions arising or enable the stored energy to be safely dissipated.

Protection against failure
Every plant item in which the pressure can exceed the safe operating limit (i.e. those which have not been designed to withstand the maximum pressure which can be generated within the system) should be protected, whenever operational, by at least one pressure-relieving or pressure-limiting device.

The device should be suitable for its intended duty and should be fitted as close as practicable to the plant item it is designed to protect. Sufficient devices should be fitted at other points to ensure that the pressures inside the system do not exceed the safe operating limits. In the event of a pressure-relief device operating, the design should enable the contents to be released in as safe a manner as is practicable.

Suitable measuring or indicating devices should be provided to give clear indications of relevant critical conditions within the system, e.g. temperatures, pressures, liquid levels. The display of any measuring equipment should be clearly visible. It should be possible to see when safe operating limits are being reached. Suitable moisture filters and/or drains should be provided where moisture would adversely affect the integrity of the system or the operation of any protective device.

Equipment, such as boilers, in which a low level (or into which a low flow rate) of water could lead to unsafe conditions should be fitted with at least one suitable water level indicator and to an alarm which sounds when the water level drops to a predetermined value. The indicator should be connected directly to the equipment. Fusible

plugs should only be used as the sole low water alarm when other types of low water alarm are not practicable. They should be fitted at the point or points where overheating is first likely to occur if the water level drops. The gauge glasses of tubular water level gauges should be effectively protected to prevent injury from the effects of the glass breaking and the contents being ejected.

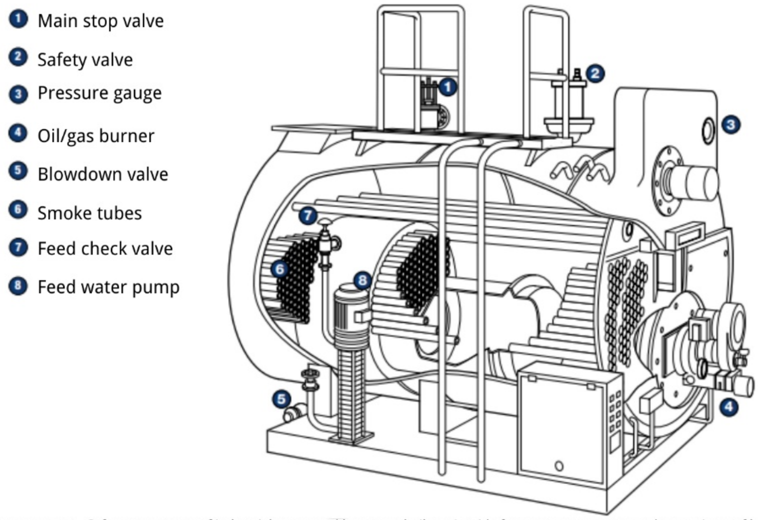


Image source - Safe management of industrial steam and hot water boilers: A guide for owners, managers and supervisors of boilers, boiler houses and boiler plant INDG436 (hse.gov.uk)

The pressure-relieving device should be so designed that it will deal adequately, where appropriate, with the dynamic flow characteristics of those fluids which result in two-phase flow conditions.

The devices and associated inlet and outlet pipe work should have an adequate discharge capacity to limit pressure to within the safe operating limits. It should reach full discharge capacity within a set limit of overpressure (accumulation). The normal operating pressure of the system should be sufficiently below the setting of the protective device to prevent its premature operation.

Construction materials
Materials used in construction should be suitable for the intended use. Account should be taken of the intended duty of the valve, including pressure, temperature, size, frequency of use, nature of contents and any foreseeable fault conditions, when selecting valves. The direction of opening and closing should preferably be indicated on valves.

External forces
Account should be taken of any external forces which could affect the integrity of the equipment. These may include the forces exerted on pipe work from thermal expansion and contraction, externally applied loads or any reasonably foreseeable vibration or shock loading, for example from water hammer. Suitable expansion bends and/or joints and drains should be incorporated in the pipe work, as necessary.

Safe access
Any equipment (such as an autoclave) to which regular access is required during process operations, e.g. for loading and unloading, should be provided with suitable door safety devices. The function of these devices is to securely fasten any door while it is subjected to internal pressure and thereby prevent the risk of the door being violently blown open. The devices should ensure that the vessel cannot be pressurised until the door is securely closed. It should not be possible to open the door until the internal pressure has been fully and suitably vented to atmospheric pressure. The door should be restrained for the first part of its travel until the seal has been broken.

Repair and modification
When designing any modifications (including extensions or additions) or repairs to the pressurised parts of the system, whether temporary or permanent.

The following should be considered:

- The original design specification.
- The duty for which the system is to be used after the repair or modification, including any change in relevant fluid.
- The effects any such work may have on the integrity of the pressure system.
- Whether the protective devices are still adequate.
- Continued suitability of the written scheme of examination.

Repair or modification of non-pressure containing parts of the system should be carried out so that the integrity of the pressure system is not adversely affected. This should ensure that any repairs, modifications (including extensions or additions) do not affect the operation of any protective devices.

Any repair or modification (including extensions or additions) should be designed in accordance with appropriate standards, considering the expected future duty of the system as well as the original design specification. It should be done by a person competent to do such work.

Where substantial modifications or repairs (including extensions or additions) are to be carried out which might increase the risk of system failure, the user should consult a person who is competent to advise before work begins.

Information and marking
The designer or supplier of a pressure system or component part should consider the most effective way of providing the appropriate information to those who need it.

Additional information about pressure vessels and information relevant to the whole system should be provided in writing, so that users/owners are supplied with sufficient information on the design, construction, examination, operation, and maintenance of the equipment. The designer or supplier should use their judgement, knowledge, and experience to decide what information is required.

The following items should be considered where relevant design standards used and evidence of compliance with national/European/international standards or documentation showing conformity:

- Design pressures (maximum and minimum)
- Fatigue life
- Design temperatures (maximum and minimum)
- Creep life
- Intended contents, especially where the design has been carried out for a specific process
- Flow rates and discharge capacities
- Corrosion allowances
- Wall thickness
- Volume capacities, especially for storage vessels. Depending on the intended contents these may be expressed as maximum volume, pressure, or filling ratio
- Materials of construction

There may be several stages in the supply chain before the equipment reaches the user/owner. For example, components such as safety devices fabricated by others may be used by a manufacturer or installer of a complete vessel or system. It is important that all relevant information is passed on at each stage of the production or supply process. However, the manufacturer does not have to provide a statement of the safe operating limits if sufficient information is provided to enable the safe operating limits to be determined.

Safe operating limits
These are the limits beyond which the system should not be taken.
Where the system consists of a standard production item, the designer/manufacturer should assess the safe operating limits and pass the relevant information to the user/owner. In these circumstances, the user/owner will not always need to carry out the detailed work required to establish the safe operating limits of the system. In cases where the user/owner has specified the design, the responsibility for establishing the safe operating limits rests with the user/owner.

If the user/owner does not have sufficient technical expertise to establish the safe operating limits, an organisation which is competent to carry out the task should be used.

The exact nature and type of safe operating limits which need to be specified will depend on the complexity and operating conditions of the system. Small, simple systems may need little more than the establishment of the maximum pressure for safe operation. Complex, larger systems are likely to need a wide range of conditions specified, e.g. maximum and minimum temperatures and pressures, nature, volumes and flow rates of contents, operating times, heat input or coolant flow. In all cases the safe operating limits should incorporate a suitable margin of safety.

Written scheme of examination
Before a pressure system is operated the user/owner must ensure that a written scheme of examination has been prepared. The written scheme of examination should be drawn up by a competent person, or if drawn up by someone other than a competent person, certified as suitable by a competent person.

The responsibility for ensuring the scope of the written scheme of examination is suitable rests with the user/owner. The user/owner should first establish which parts of the pressure system are pressure vessels, protective devices, and then decide which parts of the system should be included in the written scheme.

The following points should be considered:

- In general, pressure vessels should be included (it might be reasonable to exclude small vessels with low stored energy which form part of a larger system).
- All protective devices should be included, even if they are on a part of the system which is not included.
- Pipe work, which is widely defined to include pipes, associated valves, pumps, compressors, hoses, bellows, and other pressure-containing components, will only need to be included in the scheme if:
- Its mechanical integrity is liable to be significantly reduced by corrosion, erosion, fatigue, or any other factors.
- Failure resulting in the sudden release of stored energy would give rise to danger.

As a minimum, the following information should be included in the written scheme of examination:

- Those parts of the system which are to be examined.
- Identification of the item of plant or equipment.
- The nature of the examination required, including the inspection, and testing to be carried out on any protective devices.
- The preparatory work necessary to enable the item to be examined safely.
- Specify what examination is necessary before the system is first used, where appropriate.
- The maximum interval between examinations.
- The critical parts of the system which, if modified or repaired, should be examined by a competent person before it is used again.
- The name of the competent person certifying the written scheme.
- The date of the certification.

Maintenance and record keeping

Maintenance

The type and frequency of maintenance for the system should be assessed and a suitable maintenance programme planned.

A suitable maintenance programme should take account of:

- The age of the system.
- The operating/process conditions.
- The working environment.
- The manufacturer's/supplier's instructions.
- Any previous maintenance history.
- Reports of examinations carried out under the written scheme of examination by the competent person.
- The results of other relevant inspections (e.g. for maintenance or operational purposes).
- Repairs or modifications to the system.
- The risks to health and safety from failure or deterioration.

Problems identified during operation of the system should be assessed for their impact on the safety of the system. For instance, recurrent discharge of a relief valve may indicate that the system or the relief valve is not working correctly and should be investigated as part of the planned maintenance regime.

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The type and frequency of maintenance tasks (inspections, replacement of parts, etc.) should be decided for all those parts which, through failure or malfunction, would affect the safe operation of the system. Although pipe work systems may not always be included for examination under the written scheme, checks and remedial action in potentially vulnerable areas such as expansion loops, bends, dead legs, and low points or where leaks have been noticed will be necessary.

Systems which have been out of service for a significant period will need detailed checks and maintenance before being returned to service, irrespective of any examinations carried out under the written scheme.

Record keeping
A suitable system for recording and retaining information about safe operating limits and any changes to them should be used. Where the limits have been specified by the designer or manufacturer, then the operating manual supplied with the system should be used to pass on the information. Larger or more complex systems may have the information recorded in several documents. Whatever method is used, the information should be readily available to those people who need it, including the competent person responsible for the examinations in accordance with the written scheme. It is recommended that the details of the safe operating limits are made available to the person operating the system and retained with other relevant documentation.

For mobile systems, the owner must provide the user with a written statement detailing the safe operating limits or ensure that this information is clearly marked on the equipment. Where the system is likely to be on hire for long periods, both a written statement and durable marking are preferable. This should ensure that information about the safe operating limits is always readily available.

Competent persons
It is the responsibility of the user/owner to select a competent person capable of carrying out the duties in a proper manner with sufficient expertise in the system. In some cases, the necessary expertise will lie within the user's/owner's own organisation. In such cases, the user/owner is acting as a competent person and is responsible for compliance with any legal requirements relating to the system. However, small, or medium-sized businesses may not have sufficient in-house expertise. If this is the case, they should use a suitably qualified and experienced independent competent person. Whether the competent person is drawn from within the user's/owner's organisation or from outside, they should have sufficient understanding of the systems in question to enable them to draw up schemes of examination or certify them as suitable.

A competent person capable of drawing up schemes of examination or examining a simple system may not have the expertise, knowledge, and experience to act as the competent person for more complex systems. For several systems, including the larger or more complex, it is unlikely that one individual will have sufficient knowledge and expertise to act on their own. A competent person should be chosen who has a team of employees available with the necessary breadth of knowledge and experience.

In general terms, the competent person should have:

- The practical and theoretical knowledge and actual experience of the relevant systems.
- Access to specialist services.
- Effective support and professional expertise within their organisation.

- Proper standards of professional integrity.

Where the competent person is a direct employee of the user's/owner's organisation, there should be a suitable degree of independence from the operating functions of the company. Where the staff are provided from an in-house inspection department and carry out functions in addition to their competent person duties, they should be separately accountable under their job descriptions for their activities as competent persons. They should act in an objective and professional manner with no conflict of interests and should give an impartial assessment of the nature and condition of the system.

The competent person is responsible for all examinations. For example, where ancillary examination methods (e.g. non-destructive testing) are undertaken by another person or body, the competent person should accept responsibility for the results of these tests and their interpretation.

10.8: Machinery

Safety integration and machinery risk assessment

Definition of machinery

The ILO Code of practice "Safety and health in the use of machinery" defines machinery as:

" *An assembly fitted with, or intended to be fitted with, a drive system other than one using only directly applied human or animal effort, consisting of linked parts or components, at least one of which moves, and which are joined together for a specific application*."

Role and Application of Standards Relating to Machinery

Standards can exist at many levels and include:

- International standards (prefixed by "ISO" or "EN", sometimes by both)
- National standards (e.g. British Standards prefixed by "BS")
- Industrial/sector
- Even in-house

Standards have been defined as "an agreed, repeatable way of doing something" (BSI). Normally they are published documents containing technical information to guide or define practice in a consistent way and are usually used by designers and manufacturers of products. They are also used by customers when specifying products, and authorities when checking product compliance.

Normally the use of standards is voluntary and they do not impose legal responsibilities. However, in some cases, legislation may "call-up" a specific standard effectively giving it legal force, or their use by a manufacturer may be declared, effectively binding that person and their product, to the requirements of the standard.

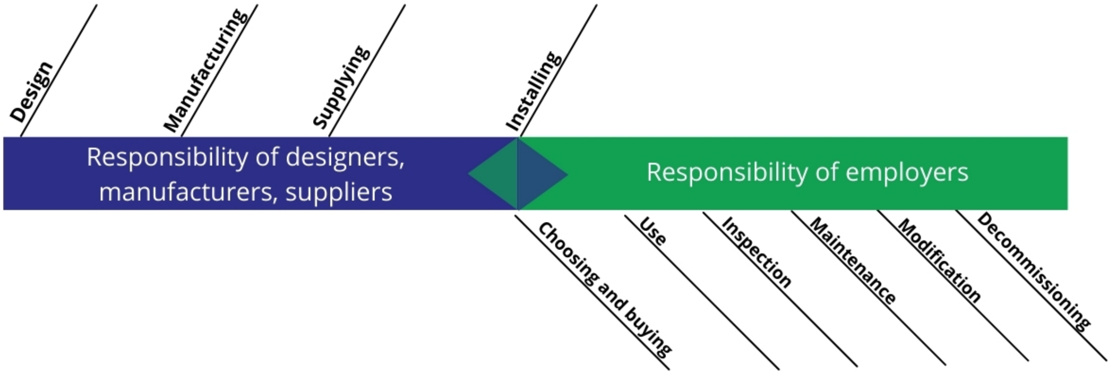
ILO Guarding of Machinery Convention C119 and International Standards
Article 6 of the above conventions states:

1. "The use of machinery any dangerous part of which, including the point of operation, is without appropriate guards shall be prohibited by national laws or regulations or prevented by other equally effective measures......

2. Machinery shall be so guarded as to ensure that national regulations and standards of occupational safety and hygiene are not infringed".

National laws that have been introduced to facilitate machinery guarding and safety include the UK Provision and Use of Work Equipment Regulations - PUWER (as a result of a European directive).

The ILO Code of practice " Safety and health in the use of machinery" highlights responsibilities for ensuring machinery safety,



EN ISO 12100: Safety of Machinery, General Principles for Design

ISO 12100:2010 (ISO 12100) specifies basic terminology, principles, and a methodology for achieving safety in the design of machinery. It specifies principles of risk assessment and risk reduction to help designers achieve this objective. These principles are based on knowledge and experience of the design, use, incidents, accidents, and risks associated with machinery. Within the standard, procedures are described for identifying hazards and estimating and evaluating risks during relevant phases of the machine life cycle, and for the elimination of hazards or sufficient risk reduction.

ISO 12100 defines three types of standards representing different levels of detail:

- *type A* standards establish general, overarching guiding principles.
- *type B* standards have specific design principles for a specific technology.
- *type C* standards are application-specific standards.

A type A standard itself, ISO 12100 is also intended to be used as a basis for the preparation of type B and type C safety standards.

ISO 12100 provides the risk management framework for machinery, predictive modelling, and risk analysis at laboratory level. It defines the principles of how to do risk management for machinery: the different scenarios in which machines can operate in an unsafe manner, and so forth. It is those principles that are then applied at the technology level and the application level to make sure that the right risk management process has been followed, and that the risk controls implemented on the technology are appropriate to the specific hazards that may occur due to an application.

The risk assessment guidelines provided in ISO 12100 are presented as a series of logical steps. These will help designers to systematically determine the limits of the machinery; identify risks of hazards such as crushing, cutting, electric shock, or fatigue; and estimate potential dangers ranging from machine failure to human error.

For those running a manufacturing plant, when buying equipment, regardless of who manufactures the product, they need to consider whether it will integrate well and support ISO 12100 compliance and the dictates of the Machinery Directive (Directive 2006/42/EC).

ISO/TR 1412: Safety of Machinery, Risk Assessment

ISO/TR 1412 gives practical guidance on conducting a risk assessment for machinery in accordance with ISO 12100 and describes various methods and tools for each step in the process.

It gives examples of different measures that can be used to reduce risk and is intended to be used for risk assessment on a wide variety of machinery in terms of complexity and potential for harm.

Its intended users are those involved in the design, installation or modification of machinery (for example, designers, technicians or safety specialists).

The Principles of Safety Integration

Machinery Directive 2006/42/EC lays down the principles of safety integration as follows:

(a) Machinery must be designed and constructed so that it is fitted for its function, and can be operated, adjusted and maintained without putting persons at risk when these operations are carried out under the conditions foreseen but also considering any reasonably foreseeable misuse thereof.

The aim of measures taken must be to eliminate any risk throughout the foreseeable lifetime of the machinery including the phases of transport, assembly, dismantling, disabling and scrapping.

(b) In selecting the most appropriate methods, the manufacturer or his authorised representative must apply the following principles, in the order given:

- Eliminate or reduce risks as far as possible (inherently safe machinery design and construction).
- Take the necessary protective measures in relation to risks that cannot be eliminated.
- Inform users of the residual risks due to any shortcomings of the protective measures adopted, indicate whether any training is required and specify any need to provide personal protective equipment.

(c) When designing and constructing machinery and when drafting the instructions, the manufacturer or his authorised representative must envisage not only the intended use of the machinery but also any reasonably foreseeable misuse thereof.

The machinery must be designed and constructed in such a way as to prevent abnormal use if such use would engender a risk. Where appropriate, the instructions must draw the user's attention to ways — which experience has shown might occur — in which the machinery should not be used.

(d) Machinery must be designed and constructed to take account of the constraints to which the operator is subject because of the necessary or foreseeable use of personal protective equipment.

(e) Machinery must be supplied with all the special equipment and accessories essential to enable it to be adjusted, maintained and used safely.

Factors to be Considered When Assessing Risk

The risk assessment process for machinery starts with the determination of limits of the assessment in terms of use, space and duration.

The factors to be considered when assessing risk: persons at risk, the severity of possible injury, the probability of injury, need for access, duration of exposure, the reliability of safeguards, operating procedures, and personnel.

Persons at risk
The assessment should consider persons at risk at all stage of the lifecycle of the machinery.

Including those involved in:

- Installation, assembly, testing/commissioning
- Operating the machinery
- Maintaining/adjusting/repairing
- Work near machinery
- Dismantling the machinery

Severity of possible injury
The severity can be estimated by considering the following:

- The severity of injuries or damage to health (for example, slight, serious, death).
- The extent of harm (for example, to one person, several persons).

When carrying out the risk assessment, the risk from the most likely severity of the harm that is likely to occur from each identified hazard should be considered, but the highest foreseeable severity should also be considered, even if the probability of such an occurrence is not high.

Probability of injury
The exposure of a person to the hazard influences the probability of the occurrence of harm.

Factors to be considered when estimating the exposure are:

- The need for access to the hazard zone (for normal operation, correction of malfunction, maintenance or repair, etc.).
- The nature of access (for example, manual feeding of materials).
- The time spent in the hazard zone.
- The number of persons requiring access.
- The frequency of access.

The occurrence of a hazardous event influences the probability of occurrence of harm.

Factors to be considered when estimating the occurrence of a hazardous event include:

- Reliability and other statistical data
- Accident history
- History of damage to health
- Comparison of risks (for example, with similar machinery)

(Note: the occurrence of a hazardous event can be of a technical or human origin).

Type, frequency, and duration of exposure
The estimation of the exposure to the hazard under consideration (including long-term damage to health) requires analysis of and shall account for, all modes of operation of the machinery and methods of working. The analysis shall account for the needs for access during loading/unloading, setting, teaching, process change over or correction, cleaning, fault-finding, and maintenance.

Human Factors
Human factors can affect risk and shall be considered in the risk estimation, including, for example:

- The interaction of worker(s) with the machinery, including correction of malfunction.
- The interaction between workers.
- Stress-related aspects.
- Ergonomic aspects.
- The capacity of workers to be aware of risks in each situation depending on their training, experience and ability.
- Fatigue aspects.
- Aspects of limited abilities (due to disability, age, etc).

Training, experience, and ability can affect risk; nevertheless, none of these factors shall be used as a substitute for hazard elimination, risk reduction by inherently safe design measure or safeguarding, wherever these protective measures can be practicably implemented.

Conformity Assessments, the Use of Harmonised Standards, the Technical File, and the Declaration of Conformity

Conformity assessment
Under Article 12 of the Machinery Directive there are three routes for conformity assessment:

- The procedure for assessment of conformity with internal checks on the manufacture of machinery provided for in Annex VIII.
- The EC type-examination procedure provided for in Annex IX, plus the internal checks on the manufacture of machinery provided for in Annex VIII, point 3.
- The full quality assurance procedure provided for in Annex X.

Where the product is explicitly mentioned in Annex IV (part 4 of Schedule 2 of the Supply of Machinery (Safety) Regulations 2008) the first option above is only available where the product is manufactured fully in accordance with transposed *harmonised standards* that cover all relevant essential health and safety requirements (EHSRs) for the product. (a *harmonised standard* is a European standard developed by a recognised European Standards Organisation: CEN, CENELEC, or ETSI. It is created following a request from the European Commission to one of these organisations)

Annex IV products include many types of woodworking machinery, chainsaws, presses for the working of cold metal, manually loaded and unloaded compression moulding machines for plastics and rubber, certain types of lifting equipment, as well as various safety components, including logic units ensuring safety functions.

Only the second and third options above are permitted for the conformity assessment of Annex IV products that are:

- Not manufactured in conformity with transposed harmonised standards, or
- Only partly in accordance with such standards, or
- If the harmonised standards do not cover all the relevant EHSRs, or
- If no harmonised standards exist for the product in question.

Both options (2 & 3 above) require the involvement of a notified body (independent organisations appointed and accredited by member states to undertake conformity assessment of products within their accreditation and competency on behalf of the Responsible Person.).

The Technical File

Manufacturers of new products subject to European product safety Directives must collect and be able to assemble comprehensive information covering the design, construction, conformity assessment and use of the product to demonstrate how their product complies with all applicable Directives. This is known as a technical file. It should be in one or more of the official Community languages and kept available for at least the time specified in the relevant Directive (e.g. for machinery this means for at least 10 years since the last production of the product range).

The file is required so that as the manufacturer you can demonstrate with appropriately detailed documentation, calculations, and drawings, how your product complies with all relevant Directives, and so is safe during all phases of its life.

The file would generally contain:

- Information concerning the products design assessment and construction, including information showing how relevant essential requirements have been met (which may include references to technical standards applied).
- The conformity assessment procedure applied to the product.
- A copy of the Declaration of Conformity (and any other Declarations of conformity or Incorporation relevant to the product or its subassemblies).
- A copy of the User Instructions
- Details of relevant research and test reports
- And where a series of products are made, details of the quality systems to assure the safety of those products.

Normally the technical file does not have to be permanently available in material form, nor located within the territory of the Community, provided it is capable of being assembled and made available in a reasonable period.

Declaration of Conformity

Most new products must be supplied to end users with a certificate called a Declaration of Conformity which must relate to the product placed on the market.

It is a formal declaration by a manufacturer, or the manufacturer's representative, that the product to which it applies meets all relevant requirements of all product safety directives applicable to that product.

This document should declare key information, including:

- The name and address of the organisation taking responsibility for the product.
- A description of the product.
- List which product safety Directives it complies with.
- May include details of relevant standards used.

- Be dated, and signed by a representative of the organisation placing it on the EU market.

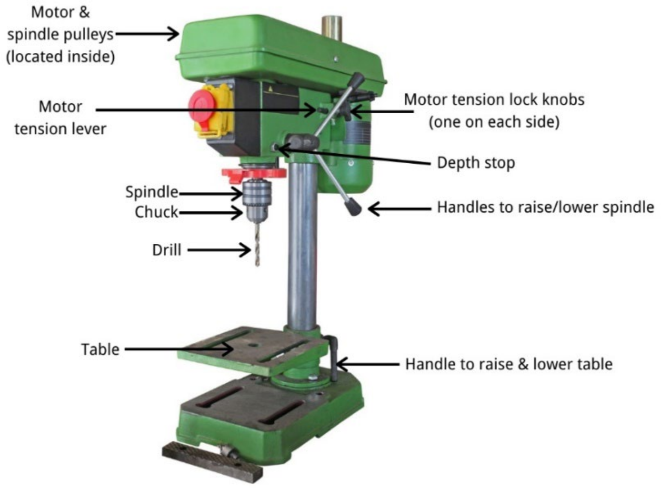
A Declaration of Conformity is not a quality certificate, nor a guarantee for safety. However, when properly drawn up along with CE marking on the product, conformity of the product with the Directive(s) quoted on the Declaration of Conformity may be presumed by suppliers in the distribution chain and by the end customer, provided there are no obvious or known defects.

Generic hazards

Common Machinery Hazards in a Range of General Workplaces

Drills (Radial arm and pedestal)
These are used for boring holes in materials such as wood, plastic, metal.

The main mechanical hazards are puncture or stabbing from the drill; ejection/cut hazards from the waste materials produced (known as "swarf"); the possibility of entanglement (hair, clothing, jewellery) due to the rotation of the drill and drawing in if the guard is missing from the pulley belt drive.



Non-mechanical hazards include electricity, noise, high temperature (due to the heat generated during the drilling process) and coolants or lubricating fluids used.

Circular Saws
These have a very sharp circular blade, set within a table, rotating at high speed, and are mainly used for cutting wood.

The main mechanical hazard is cutting, from the blade.

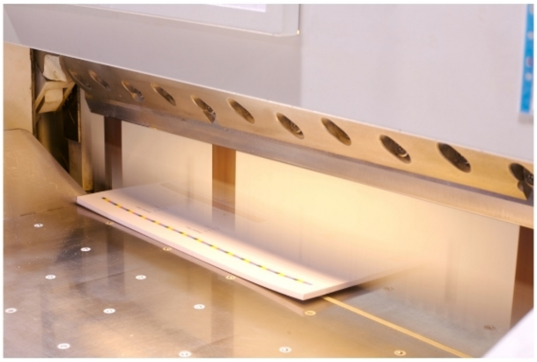
Non-mechanical hazards include noise, electricity, and wood dust.




Guillotines
Used for cutting materials such as paper and metal.

The operation of a guillotine means that the main mechanical hazards are cuts from the blade.

Modern industrial guillotines are often electrically operated with the associated non-mechanical hazards of noise (on large machines) and electricity.

Sanding Machines (belt and disc)
Used to smooth materials such as woods and plastics. It is also used to remove small amounts of waste material.

Mechanical hazards include abrasions from contact with the sander disc or belt; ejected particles and drawing in from any exposed belt drive pulley.

Non-mechanical hazards include electricity and dust.


Abrasive Wheels
Used for removing surface material from metals or plastics to smooth the surface. (for example, removing burred edges, or sharpening a chisel).

They work by bringing the work piece into contact with a high-speed rotating wheel made of an abrasive substance, often with a coolant being used on the work piece during the process.

Mechanical hazards include abrasions from contact with the wheel; drawing in between the wheel and the tool rest; ejected particles from the wheel (wheel rupture in worst case).

Non-mechanical hazards include electricity; noise; exposure to hazardous substances (coolant).

Lathes
A lathe is a machine for shaping wood, metal, or other material by means of a rotating drive which turns the piece being worked on against changeable cutting tools.

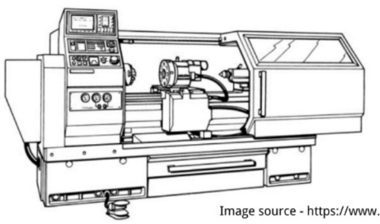


Image source - https://www.hse.gov.uk/pUbns/priced/hsg129.pdf

Mechanical hazards include *entanglement* (on chuck or rotating stock bar) *ejection* of *swarf*

ejection of chuck key if left in, *drawing into* pulley drive if unguarded.

Non-mechanical hazards include *electricity*; exposure to *hazardous substance* (coolant or lubricant).

Automatic Doors and Gates
Mechanical hazards include impact with a closing door or gate or crushing (between too gates or a door and fixed object).

Non-mechanical hazard is electricity.

Mechanical and Hydraulic Presses
This type of equipment uses force to mould shapes into raw materials such as plastic or metal. Presses can also be used to compress two components together.

Crushing and impact injuries can result from contact with the press when it is in operation. Hydraulic presses also carry a risk of injury from high pressure liquid if there is a leak on a hydraulic pipe or if the pipe suddenly ruptures. These are the mechanical hazards.

Non-mechanical hazards can include:

- Noise - from the running of the press and the impact noises.
- Vibration - from the press running, the impact and the movement of raw materials e.g. where large sheets of metal are used, the vibration from the machine can be transferred through the materials.
- Electricity - from the press itself or static from the raw material.

Portable Power Tools

There are a vast number of power tools currently available for use. They include drills, grinders, concrete cutters, sanders, and electric/petrol driven grass strimmer's.

Hazards depend on the tool being used. For example:

Grass strimmer:

- Mechanical: entanglement on rotating cutter; ejection of stones/debris; cuts from "blades"
- Non-mechanical: noise; vibration; electricity/petrol; biological (pollen/faeces); ergonomic (for large industrial types)

Concrete cutter:

- Mechanical: cuts from blade

- Non-mechanical: noise; vibration; electricity/petrol; dust; ergonomic

CNC Machines
CNC Machining is a process used in the manufacturing sector that involves the use of computers to control machine tools.

Tools that can be controlled in this manner include lathes, mills, routers, and grinders. The CNC in CNC Machining stands for Computer Numerical Control.

One of the main advantages of CNC machines is that they are much safer than manually operated machines. Most modern CNC machines are designed so that the cutting tool will not start unless the guard is in position. Also, the best CNC machines automatically lock the guard in position whilst the cutter is shaping material. The guard can only be opened if the cutter has stopped.

Mechanical hazards depend on what type of machine is used (for example lathe, milling machine).

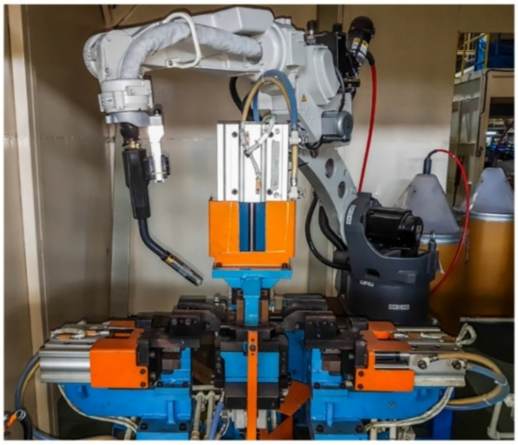
Non-mechanicals hazards will usually include electricity and noise.

Robotics
More and more production processes involving repetitive tasks are now being automated.

However, even though the human element has been removed, there are still hazards that surrounding workers need to be aware of:

- Mechanical hazards - impact and ejection of debris.
- High pressure - robots operated by hydraulics may develop a fault leading to hydraulic fluid being ejected at high pressure.
- Electricity - this can come from a fault on the wiring of the robot or surrounding power source.

- Job specific hazards - even though the process is automated, the hazards from the tasks will stay the same e.g. welding where surrounding workers can still be exposed to hazards such as arc eye, hot sparks, fumes.



The hazards, advantages and disadvantages associated with artificial intelligence

The term “artificial intelligence (AI) was invented by John McCarthy in 1950. It is one of the emerging technologies that tries to simulate human reasoning in AI systems.

Artificial Intelligence is the ability of a computer program to learn and think.

Anything that involves a programme doing something that would normally rely on the intelligence of a human, can be considered artificial intelligence (for example, CNC machines).

Advantages of AI include:

- Reduction in human error
- Takes risks instead of Humans
- Available 24 hours a day, 365 days a year
- Helps avoid the boredom of repetitive tasks
- Makes decisions faster

Disadvantages include:

- Expensive
- Makes humans “lazy”
- Increases unemployment
- No “out of the box” thinking

Machinery control systems

What is a Control System?

A control system responds to input signals from the machine or from the operator and generates output signals.

These make the machine operate in a desired manner. So, if for **e**xample, an operator presses a start button then the control system may respond by closing a contactor and energising a motor.

Electro technical control systems can range from simple electromechanical relay based systems to complex programmable systems with multiple analogue and digital inputs and outputs.

What is a Safety Related Control System?
A control system in a machine should be regarded as being safety-related if it contributes to reducing the occurrence of a hazardous situation or if it is required to function correctly to maintain or achieve safety. The functions carried out by a safety-related control system are termed safety functions.

Generally, safety functions either prevent the initiation of a hazard or detect the onset of a hazard. Safety-related control systems should be designed and configured to be reliable enough (bearing in mind the consequences of any failure) and to perform the necessary functions to achieve or maintain a safe state or mitigate the consequences of a hazard.

Parts of machinery control systems that are assigned to provide safety functions are called safety-related parts of control systems and these can consist of hardware and software and can either be separate from the machine control system or an integral part of it. In addition to providing safety functions, safety related parts of control systems can also provide operational functions (e.g. two-handed controls as a means of process initiation).

Fail Safe
A "fail-safe" in engineering is a design feature or practice that in the event of a specific type of failure, inherently responds in a way that will cause no or minimal harm to other equipment, the environment or to people.

A system's being "fail-safe" means not that failure is impossible or improbable, but rather that the system's design prevents or mitigates unsafe consequences of the system's failure. For example:

- Air brakes on railway trains and air brakes on trucks. The brakes are held in the "off" position by air pressure created in the brake system. Should a brake line split, or a carriage become de-coupled, the air pressure will be lost and the brakes applied by springs. It is impossible to drive a train or truck with a serious leak in the air brake system.
- An interlock guard mechanism failure on a machine should render the machine inoperable - not retain its functionality.

Controls for Starting or Making a Significant Change in Operating Conditions
It should only be possible to start the equipment by using appropriate controls. Operating the control need not necessarily immediately start the equipment as control systems may require certain conditions (for example those relating to operation or protection devices) to be met before starting can be achieved.

Restarting the equipment after any stoppage is subject to the same requirements.

The stoppage may have been deliberate or may have happened, for example by the activation of a protection device. Operators should not normally be able to restart the equipment simply by resetting a protection device such as, for example, an interlock or a person’s withdrawal from an area covered by a sensing device - operation of the start control should also be required.

Any change in the operating conditions of the equipment should only be possible using a control unless the change does not increase risks to health and safety.

Examples of operating conditions include speed, pressure, temperature, and power. For example, certain multifunctional machines are used in the metalworking industry for punching or shearing metal using different tools located on different parts of the machines.

Safety in the use of these machines is achieved by means of a combination of safe systems of work and physical safeguards which match the characteristics of the work piece. It is essential that the function of the machine (for example punching or shearing) is changed by a conscious, positive action by the operator and that unused parts of the machine cannot start up unintentionally.

In the case of automatic machinery such as those controlled by programmable electronic systems, it is not appropriate to require separate controls for changing operating conditions when such changes are part of the normal operating cycle. However, where interventions outside the normal sequence, such as clearing blockages, setting or cleaning, proper controls (e.g. start and stop) should be provided.

The controls provided should be designed and positioned to prevent inadvertent or accidental operation. Buttons or levers, for example, should have an appropriate shrouding or locking facility.

Stop Controls
The action of the stop control should bring the equipment to a safe condition in a safe manner. This acknowledges that it is not always desirable to bring all items of work equipment immediately to a complete stop if this could result in other risks. If needed, to ensure the safety of the operator, it is acceptable that the operation of the stop control brings the equipment to rest in sequence or at the end of an operating cycle.

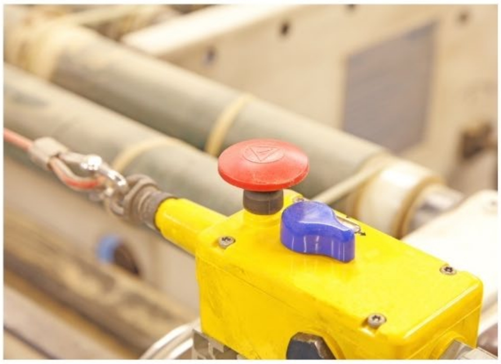
The stop control should take priority over any operating or start control. Where possible, it should not require anything other than a short manual action to activate it, even though the stop and disconnection sequence that is initiated may take some time to complete.

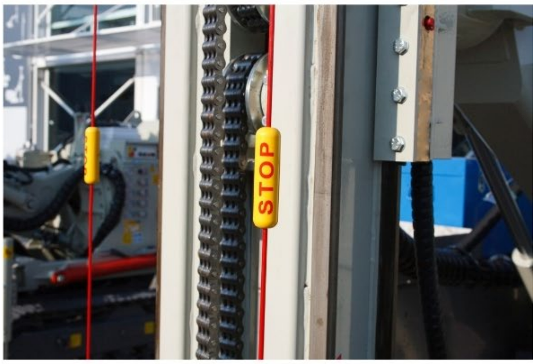
Emergency Stop Controls
An emergency stop control should be provided where the other safeguards in place are not adequate to prevent risk when an irregular event occurs. However, an emergency stop control should not be considered as a substitute for safeguarding. Where it is appropriate to have one, based on the risk assessment, an emergency stop should be provided at every control point and at other appropriate locations around the equipment so that action can be taken quickly.

Emergency stops are provided to enable a rapid response to potentially dangerous situations, they should not be used to stop the equipment during normal operation.

If emergency stop controls are considered necessary, they should be easy to reach and easy to use.

The usual way of providing this is in the form of a mushroom-headed push button, which the operator strikes in the event of an emergency. They must be strategically placed in sufficient quantity around the machine to ensure that there is always one in reach at a hazard point.





For machinery such as conveyors, etc. it is often more convenient and effective to use a grab-wire device along the hazard area. These devices use a steel wire rope connected to latching pull switches so that pulling on the rope will operate the switch and cut off the machine power.

Markings and Ergonomic Principles

Start, stop and emergency stop controls should be clearly marked, and positioned, to prevent the possibility of inadvertent operation.

Standards EN 60073, DIN EN 60204 and IEC 60204-1: 1997 specify the recommended colours in the table below.

Colour	Meaning	Explanation	Examples of application
RED	Emergency	Actuate in the event of a hazardous condition or emergency	EMERGENCY STOP Initiation of EMERGENCY STOP functions, conditional for STOP/OFF
YELLOW	Abnormal	Actuate in the event of an abnormal load	Intervention to suppress an abnormal condition Intervention to restart an interrupted automatic cycle
GREEN	Normal	Actuate to initiate normal conditions or normal status	START/ON, however WHITE should preferably used
BLUE	Mandatory	Actuate for a condition requiring mandatory action	Reset function
WHITE	No specific meaning assigned	For general initiation of functions except for EMERGENCY STOP	START/ON (preferred), STOP/OFF
GREY			START/ON STOP/OFF
BLACK			START/ON STOP/OFF (preferred)

For each of the worker/machine interfaces, specific considerations need to be taken into account. During machine operation, special attention should be focused on the design of controls and displays.

Controls and displays should be easy to use, consistent with other machines and compatible with human expectations and capabilities.

They should be positioned so that they can be seen and accessed easily; this is especially true for any emergency controls.

Controls and displays should be designed so that they are adjustable. This can best be achieved by mounting them on articulating arms so that workers of different heights can use them comfortably.

10.9: Mobile work equipment and Lifting equipment

Mobile work equipment

What is Mobile Work Equipment?

Mobile work equipment is any work equipment which carries out work while it is travelling or which travels between different locations where it is used to carry out work. Such equipment would normally be moved on, for example, wheels, tracks, rollers, skids, etc.

Mobile work equipment may be self-propelled, towed or remote controlled and may incorporate attachments.

Self-propelled
Self-propelled mobile work equipment is work equipment which is propelled by its own motor or mechanism. The motor or mechanism may be powered by energy generated by the mobile work equipment itself, for example by an internal combustion engine, or through connection to a remote power source, such as an electric cable, electric induction or hydraulic line.

Towed
Towed mobile work equipment refers to self-supporting equipment pulled behind a powered vehicle. Some equipment will have moving parts that:

- Draw power from the towing vehicle e.g. a power harrow used to cultivate soil.
- Has its own integral source of power e.g. a crop sprayer.
- Has no moving parts and rely on the movement of the towing vehicle to operate e.g. a plough.



Remote controlled
Remote-controlled mobile work equipment is operated by controls which are not physically connected to it, for example, radio control.

Pedestrian controlled

The Application of Different Types of Mobile Work Equipment

Lift trucks
The lift truck is versatile and therefore an essential piece of equipment for many workplace operations. An assessment should be made of the environment, load, and task and the characteristics of the truck before selecting the correct lift truck. There are many different types of lift trucks, as shown below:

Counterbalance truck

This is a common type of fork lift truck used across many organisations both indoors and outside. The load at the front of the chassis is counterbalanced by a large weight built into the rear of the vehicle. There are a wide range of attachments for a counterbalance truck that would suit various work requirements and these include brick grabs, drum handlers, working platforms and safety cages.

If the truck is overloaded, or the load is incorrectly placed on the forks, it can become unstable. The stability can also be compromised if the truck is used to travel:

- With the forks raised
- Up or down an incline
- Across an uneven surface

It is therefore important to ensure that the load is correctly positioned and that the route travelled is suitable to maintain the stability of the vehicle.

The power source needs to be considered as they can run on diesel, LPG or electric. Fuel storage, fumes (especially when used indoors) and recharging are all considerations to make when selecting the right vehicle.

Reach truck

These trucks are a popular choice in many warehouses. Unlike the counterbalance, the load is partially carried over the chassis with the mast reaching out to pick up and place load. The truck has a capacity of over 2,000 kg and can lift up to 12 metres.

The operator usually sits facing the side but some models require the operator to stand. Reach trucks are popular because they are agile enough to negotiate narrow aisles in racking storage systems. These vehicles are designed for indoor use over smooth surfaces and have solid tyres on the wheels. Reach trucks are predominantly powered by battery as fumes from diesel would be an unacceptable hazard when used indoors. Consideration must be made on how and where the batteries are powered, taking into account the potential risk from fire or leaking battery acid.

Rough terrain lift truck

Rough terrain lift trucks are used mainly in construction and outside tasks as they are designed to operate on uneven surfaces. The balance is similar to a counterbalance truck. However, the movement created by negotiating rough ground can cause the load to become unstable and undermine the truck safety.

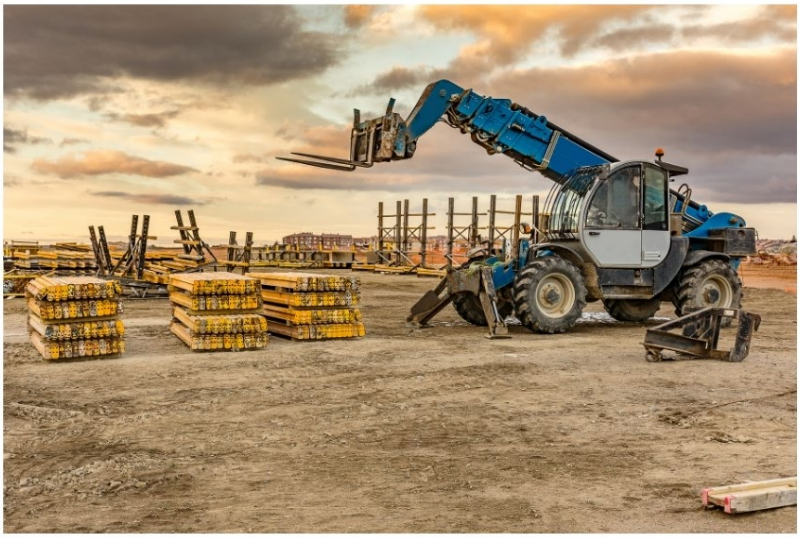
If the truck is to be used for lifting or retrieving from a high position, the ground should be stable, level and away from any walls or excavations. If it is needed on an incline, the ground should be built up appropriately to support the vehicle and load before attempting any tasks as operating on an incline can cause the vehicle to lose balance, drop the load or overturn.

A rough terrain lift truck has:

- A higher chassis position for uneven terrain.
- An enclosed operator cab to provide protection against the elements.
- Large diameter wheels with deep tread for negotiating rough terrain.
- An increased load and lifting capacity.

As the truck runs on diesel, it is not suitable for indoor work.

Telescopic materials handler



The telescopic materials handlers are also referred to as multi-tool carriers, commonly used in construction and agriculture where loads need to be positioned at different heights (different lifts of scaffold, and hay stacking).

Side Loading Truck

This is a form of lift truck commonly used to carry long loads (such as timber or heat exchanger bundles). During travel, the load is usually resting on the truck structure.

Pedestrian Controlled Truck

A pedestrian operates these via a control handle. Sometimes referred to as pallet trucks. Usually powered by a hydraulic hand pump or battery the operator can either 'ride on' or walk steering it. Operators should always face the direction of travel and not walk backwards nor directly in front of the control handle, which should act as a "dead man's handle" upon release by the pedestrian in the event of an emergency.

Agricultural tractors

Agricultural tractors are used for pulling or pushing agricultural machinery or trailers, for ploughing, tilling, disking, harrowing, planting, and similar tasks. A variety of speciality farm tractors have been developed for particular uses. They are often fitted with a power take off shaft, which allows power to be transmitted from the rear of the vehicle to other equipment, such as a plough.

Works' vehicles

Works vehicles are any vehicles used in the workplace and include:

- Dumpers
- Mobile cranes
- Tractors
- Forklift trucks

Cars, vans and large goods vehicles can be classed as work vehicles when they are used for work away from the public highway.

Mobile Equipment Hazards and Controls (as Defined by the UK HSE)

Ensuring the safety of mobile work equipment usually involves the consideration of the following:

- Overturning
- Rollover
- Passenger suitability
- Falling objects
- Excessive speed
- Failure to stop
- Unauthorised start up
- Safe operating station/platform
- Contact with wheels and tracks
- Overheating
- Contact with moving parts/drive shafts/power off-takes/wheels

Overturning

The vertical mast of a forklift truck (FLTs) will prevent an FLT overturning by more than 90 degrees, provided it has sufficient strength and dimensions for this purpose. It will also protect seated operators from being crushed between the FLT and the ground in the event of a rollover.

Dumper trucks will often have *roll over protection systems* (ROPS) fitted for the same purpose.

Where there is a risk of mobile work equipment with a seated ride-on operator can rollover in use and there is a risk of the operator leaving the operating position and being crushed between the equipment and the ground, a *restraining system*, such as a seat belt, will be required.

Rollover

In certain situations, the use of mobile equipment may give rise to a risk of rollover whilst it is travelling (for example, a dumper truck on a construction site negotiating a slope). This can result in rollover onto its side or end (i.e. through 90 degrees) or turn over completely (i.e. through 180 degrees or more).

Measures that can be taken to stabilise mobile work equipment (i.e. measures to reduce the risk of roll-over) include fitting appropriate counterbalance weights or increasing its track width by fitting additional or wider wheels. Also, moveable parts which could otherwise create instability by moving around when the mobile work equipment is travelling may be locked or lashed in stable positions, particularly where locking features are provided for such purposes, for example locking devices for excavator back hoes.

Some types of mobile work equipment will only turn onto their sides if roll-over occurs (i.e. 90-degree roll-over). For example, the boom of a hydraulic excavator, when positioned in its recommended travelling position, can prevent more than 90-degree roll-over.

ROPS are normally fitted on mobile work equipment which is at risk of 180 degrees or more roll-over. They may be structures, frames or cabs which, in the event of roll-over, prevent the work equipment from crushing the people carried by it. ROPS should be capable of withstanding the forces that they would sustain if the mobile work equipment were to roll over through 180 degrees or more.

Passenger Suitability

Operator stations with seats or work platforms normally provide a secure place on which the drivers and other people can travel on mobile work equipment.

Mobile equipment should normally be specifically designed for carrying additional passengers.

Under exceptional circumstances, mobile work equipment may be used to carry people although it is not specifically designed for this purpose, for example, trailers used to carry farm workers during harvest time.

Under these circumstances, the mobile work equipment must have features to prevent people falling from it and to allow them to stabilise themselves while it is travelling, for example, trailers with sides of appropriate height or by providing a secure handhold. People would also need to be able to safely mount and dismount.

Falling Objects

If people carried on the mobile work equipment are at significant risk of injury from objects falling on them while it is in use, a *falling object protection system* (FOPS) should be provided.

This could be a suitably strong safety cab or protective cage which provides adequate protection in the working environment in which the mobile equipment is used.

Excessive Speed

When carrying people, mobile work equipment should be driven within safe speed limits to ensure that the equipment is stable when cornering and on all the surfaces and gradients on which it is allowed to travel.

In addition, the speeds at which the mobile machinery travels should be limited to avoid sudden movements which could put people being carried at risk.

Failure to Stop

All self-propelled mobile work equipment should have brakes to enable it to slow down and stop in a safe distance and park safely.

To this end, mobile work equipment should have adequate braking capacity to enable it to be operated safely on the gradients on which it will be used and its parking brakes should be capable of holding it stationary (where appropriate, fully loaded) on the steepest incline that the mobile work equipment may be parked in use.

Unauthorised Start Up

Self-propelled work equipment should be prevented from unauthorised start up.

This can be achieved if it has a starter key or device which is issued or made accessible only to authorised people.

This means that access to starter keys and starting devices, such as removable dumper starting handles, should be controlled.

Contact with Wheels and Tracks

Where there is a foreseeable risk to contact with wheels or tracks when mobile equipment is travelling, adequate separation needs to be provided between people and the wheels and tracks.

This can be achieved by positioning cabs, operator stations or work platforms and any suitable barriers, such as robust *guard rails or fenders*, in positions which prevent the wheels and tracks being reached.

Overheating

Overheating and fires can be caused by various faults or misuses of the vehicle:

- Friction due to bearings running hot.
- Electric motors burning out.
- Lack of coolant or cooling system failure.
- Engine ceasing due to lack of fluids (oil, hydraulic).

Suitable, appropriate equipment to deal with these eventualities should be available and workers trained in how they should be used correctly. There should be provision for emergency rescue should the vehicle operator not be able to escape the cab in case of overheating or a fire. The equipment should include appropriate fire extinguishers and fire blankets as a minimum.

In order to ensure that these risks are reduced it is important that daily checks are made on fluid levels and pressures as per manufacturer's and organisational requirements. Regular maintenance on the vehicle is essential to ensure it runs correctly and that any warning systems are functional at all times.

Training should be given to operators to ensure that they understand the warnings of overheating and how to deal with overheating emergencies.

Contact with Moving Parts/Drive Shafts/Power Off-takes

A power take off or drive shaft is a mechanical device that transfers the vehicle engine power to other components within or connected to the vehicle such as a hydraulic pump on another piece of equipment. The pump generates the hydraulic fluid to flow and directs it to cylinders or additional motors on the attached equipment.

The power that is given to this process can be substantial and could cause damage to any work equipment that is connected. The drive shaft could seize and then cause parts to be ejected with speed and force. In addition, it could cause the powered equipment to overturn pulling over the powering vehicle. It could also cause the connection to buck upwards with the same result.

In order to protect workers and bystanders the following controls should be implemented:

- Slip clutches should be installed on the power input connection of the connected work equipment to protect it from damage should the drive shaft cease.
- Guards around the power output connector of the powering vehicle, the shaft and the power input equipment should be placed in order to protect people from entanglement and ejection of parts in the event of equipment break-up.

With any other moving part that is accessible, there is a danger of injury through contact, pinching, entanglement or ejection of debris. Other moving parts could include belt drives, piston, fan, lifting gear or fork masts. It is important that where contact can be made with moving parts, guards are placed to reduce the risk of injury.

When performing maintenance to these areas, guards must be replaced after work is complete before the vehicle is put back into use.

Refuelling or Charging of Mobile Work Equipment

Electrical
Hazards associated with electrically operated mobile work equipment include:

- The danger of production of hydrogen gas whilst charging the batteries.
- The manual handling implications of removing them for charges.
- Splashes from battery acid.

LPG
LPG is extremely flammable, leading to the potential for gas (LPG) operated mobile work equipment, the risk of fire and explosion, particularly when changing cylinders. Manual handling of gas cylinders also needs to be considered as a potential hazard. Also, there is potential for cold burns from the cylinder surfaces when changing cylinders.

Diesel
Hazards with diesel operated mobile work equipment include:

- Exhaust gases (such as carbon monoxide) particularly inside closed and inadequately ventilated structures.

- Hot surfaces associated with the diesel engine - which can act as a source of ignition if operated in flammable atmospheres.
- Potential spillages when refuelling, give rise to possible skin irritation and/or environmental damage (waterways or ground contamination).

Other control measures for the use of mobile work equipment

In addition to the controls highlighted previously, the following general control measures should be considered when using mobile work equipment:

Safe workplace: where vehicles are operation in the presence of pedestrians, the first consideration to segregate – with fixed barriers or road markings. If this is not reasonably practicable the use of high visibility jackets for pedestrians in high-risk areas should be adopted.

Vision aids: CCTV cameras are a popular feature of modern-day vehicles, giving drivers good all round vision when reversing.

Mirrors: Mirrors on vehicles and on blind corners on traffic routes. Types of mirrors include curved (which allow a driver to see larger area than normal); Plane mirror reflections create upright virtual images at the same or size and distance as the objects they reflect. This is why a plane mirror can be to determine exactly where something behind you is.

Fresnel lenses: The Fresnel lens provides an extra downwards view for a driver (such as a truck driver) so that at a glance he can see any vulnerable road user that might be hidden in the mirror blind spot, alongside his passenger door.

Use of Lift Trucks to Move People

Forklift trucks are primarily intended for lifting materials and not people. However, they can be used with working platforms to allow people to work at height. This should be in exceptional circumstances only, and only for occasional use. Examples might include:

Non-routine maintenance tasks for which it is impractical to hire in purpose-built access equipment.

- The replacement of light fittings in high-rise warehouses if the task is not carried out as part of periodic maintenance operations.
- Tasks that would otherwise be carried out using less safe means of access such as ladders, because it is impractical to hire in purpose-designed people lifting equipment due to the short duration and occasional nature of the task, e.g. clearing a blocked gutter.
- Checking on high-level damage to racking suspected of causing an immediate risk or checking on the condition of damaged roof lights.


Use of Attachments on Lift Trucks

Fitting an attachment may alter the characteristics of the lift truck and is likely to necessitate a reduction in the actual capacity of the lift truck. Where this is necessary it should only be carried out by a lift truck engineer or another person with equivalent qualifications.

Alternatively, it may be necessary to use a lift truck with a larger capacity. Wherever possible, the manufacturer or authorised supplier should be consulted about the suitability of an attachment for a lift truck and the necessary de-rating.

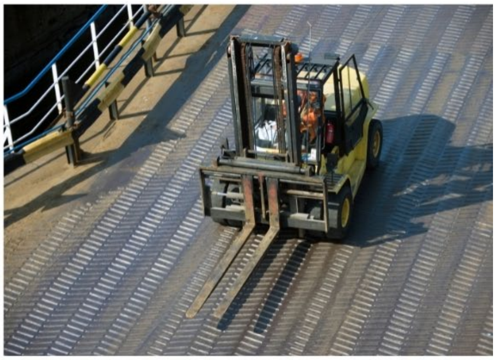
An additional capacity plate showing the de-rating necessary should be fitted to the truck. The de-rating should be related to an identified attachment.

Attachments may be mounted on the fork arms or directly onto the carriage. In all cases, the attachment should be securely fastened and care taken to ensure that the attachment or securing device does not foul any part of the mast structure during raising or lowering of the attachment.

Attachments include:

Side shift carriage
This attachment may be mounted either on the existing fork carriage or in place of it. A side shift carriage enables horizontal sideways movement of the fork arms to allow precise positioning.

Fork Positioner
This is a hydraulically operated attachment which allows the operator, while remaining in the operating position, to change the position of the fork arms relative to each other. The fork arm centres can, therefore, be adjusted to accommodate different load width.

Clamps

These attachments are designed for a variety of purposes such as lifting reels, bales, bricks or cartons. They may be used in conjunction with a rotator. The clamps may be faced with rubber or other material to improve grip.

Crane jib

This attachment may be mounted directly on the fork carriage or carried on the fork arms. A crane jib may be of a fixed length or extendible or embody many lifting points. On some it is possible to vary the angle of the jib from the horizontal.

Hydraulically operated hoppers
These attachments are usually carried on the fork arms. They are fitted with a mechanism which, when operated, causes the hopper to roll forward and discharge its contents. Once empty, the hopper returns to its normal position and re-engages the holding mechanism.

Booms
These attachments usually consist of a circular section pole mounted on the fork carriage. Designed for lifting rolls of carpet, coils of wire or similar cylindrical loads, they come in a variety of diameters and lengths.

Lifting Equipment: hazards and control measures

The applications and Types of Lifting Equipment

Introduction
The lifting of objects generally occurs on construction sites, in factories and other industrial situations. Correct lifting can move large objects efficiently and reduce manual handling operations. Incorrect lifting, however, can lead to disastrous accidents.

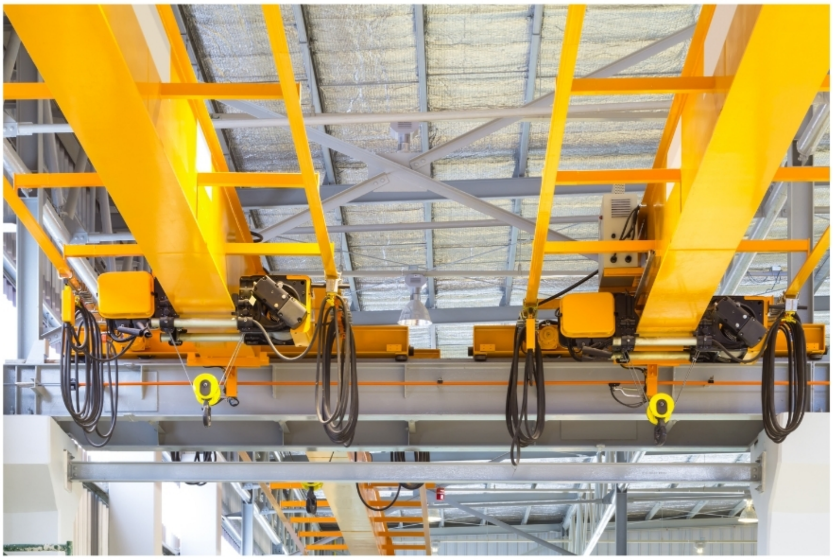
Every year, incorrect lifting procedures cause injuries, loss of work time and property. People, machinery, loads, methods, and the work environment, are all important factors for correct lifting. Provided that enough safety measures are fully implemented, lifting accidents can be reduced.

Mobile cranes
A mobile crane is a cable-controlled crane mounted on crawlers or rubber-tired carriers, or a hydraulic-powered crane with a telescoping boom mounted on truck-type carriers or as self-propelled models. They are designed to easily transport to a site and use with different types of load and cargo with little or no setup or assembly.

Tower Crane
These cranes consist of a tall, slender lattice mast with a jib unit at the top. They are used on long duration work on construction sites, where large areas of access are required to be covered with the loads. Various types are available for special situations. They are normally fixed to one location, which will give it a higher maximum capacity, but can also be mounted on rails, which would reduce the load capacity.

Overhead cranes
Generally, within buildings, although they can be found in outside situations. The rails being attached to the

structural steel framework of the building or on columns outside at a high level. They are common in engineering works and plants where lifting access for conventional cranes is difficult due to the layout (e.g. in power stations, to lift out turbines for maintenance). Capacity can be very high (200 tons is not unusual) and they are usually designed for a specific location.



The hazards associated with cranes and lifting operations

The principal hazards associated with crane and lifting operations are:

- Overturning - caused by uneven or unstable ground; outriggers not extended; severe weather.
- Overloading - by exceeding the operating capacity of the crane.
- Collision - with other cranes, vehicles, or structures.
- Contact with overhead power lines.
- Failure of a load bearing part - such as wire, jib.
- Loss of load - poor slinging procedure.
- Poor visibility - driver unable to see the load.
- Poor installation - tower cranes improperly erected.

Control measures when using cranes

Initial planning
Factors to consider when selecting lifting equipment so that it is suitable for the proposed task include:

- The load to be lifted.
- Its weight, shape, centre of gravity, availability of lifting points.
- Where the load is presently positioned and where it will be positioned after the lifting operation.

- How often the lifting equipment will be used to carry out the task.
- The environment in which the lifting equipment will be used.
- The personnel available and their knowledge, training and experience.

The person carrying out this part of the planning exercise should have appropriate knowledge and experience.

Planning individual lifting operations
For routine lifting operations, the planning of each individual lifting operation will usually be a matter for the people using the lifting equipment, such as a slinger, the crane operator.

The person carrying out this part of the planning exercise should have appropriate knowledge and experience and the organisation should have a simple plan, generic risk assessment and procedures in place to support them.

An example of a lifting plan for a routine lift using a mobile crane (assuming that the crane is sited on firm, level ground and ready to lift) would be:

- Assess the weight and size of the load.
- Choose the right accessory for lifting, e.g. depending upon the nature and weight of the load and the environment in which it is to be used.
- Check the anticipated path of the load to make sure that it is not obstructed.
- Prepare a suitable place to set down the load.
- Fit the sling to the load (using an appropriate method of slinging).
- Make the lift (a trial lift may be necessary to confirm the centre of gravity of the load; tag lines may be necessary to stop the load swinging).
- Release the slings (boards or similar may be necessary to prevent trapping of the sling).
- Clear up.

For complex or non-routine lifting operations you should plan the task each time it is carried out.

Load indicators
All cranes come with load-radius charts which give the maximum load at specified radii from the crane. There are also a number of safety devices available to assist the crane driver in ensuring that capacity is sufficient for the lift, including:

- Automatic safe load indicators - give a visual warning to the crane driver when the safe working load of the vehicle is being approached and an audible warning to the operator and surrounding work area when the safe working load is exceeded.
- Safe working load/radius indicators - indicate the safe working load applicable to the vehicle when the angle of the jib can be varied. They can operate automatically, and some can also provide read-outs for the vehicle operator.

It is important that operators are trained to understand the different alerts (visual and audible) that can be given and that they understand what corrective action is needed in these instances.

Competence of workers
All persons involved in a lifting activity must have the necessary competence to safely execute their duties. The degree of competence will depend on the task that they are undertaking.

Persons involved in a lifting operation may be:

- The person undertaking the lifting plan
- The crane driver
- The slinger
- The banks man

Lifts and Hoists
These cover any equipment used in a static location for raising or lowering a load (goods or people) where the direction of the movement is limited by guides, tracks or another form of control.

Examples include passenger lifts in buildings; hoists used for assisting hospital patients; hoists and lifts for moving materials up structures on building sites.

The difference between a lift and a hoist is that lifts have some form of cage or walls around a platform, whereas a hoist will have an open platform.



The simplest form of hoist is a *gin wheel* type, often used on construction sites, where a rope passes over a pulley at the top of the structure, with the lifting power is supplied manually or by a powered winch.

Hazards and risks
The main risks associated with lifts and hoists are:

- Falls from a height - from a landing level, because of operator or mechanical.
- Being struck by the platform or other moving parts of the hoist.
- Being struck by falling materials (from the hoist) or the hoist itself in the event of failure.

Control measures
Hoists and lifts are designed for a maximum capacity, which should be marked and displayed in a prominent position on the unit.

All hoists and lifts should be set up on solid ground. A concrete base should be installed where they are intended for long-term use.

Free-standing equipment on the outside of buildings must be secured to the structure (see the picture of builder's hoist) In practice, this often means tying (by means of rigid connections) the hoist or lift to a scaffold or to the building itself (Lifts operating inside a lift shaft are already tied in).

People must be prevented from getting underneath the lift or hoist and so being at risk from falling materials or being struck by a falling platform.

Hoists, having no enclosure on the platform itself, create the most risk of materials falling from them. A substantial enclosure at ground level is therefore required around the hoist way. The shaft of the hoist way or lift should also, where practicable, be fully enclosed, although meshing may be sufficient.

Substantial enclosure gates must also be fitted at each landing level where access to the platform is required for loading or unloading. They must be kept closed except during loading or unloading and should normally interlock with the platform so they cannot be opened when the platform is not there, thus preventing falls of people and material down the lift shaft.

Overrun trip systems, multiple ropes and hold back gears should be fitted to prevent overrunning and free fall.

Additional safety arrangements are required for hoists and lifts that are used for carrying people:

- Landing gates which only open when the lift is static (interlocked).
- Additional friction brakes that will lock onto the guide cable.
- Additional accessible cables to stabilise in case of emergency.
- An alarm system that sounds when there is a failure.

Operators must be specifically trained in the safe use of the type of lift or hoist being used which will include:

- Details of the risks and control measures involved in using the equipment.
- Awareness of the limitations of the equipment.
- Safe working loads.
- Ensuring safe working conditions such as the type of ground and weather.
- Pre-use checks that are required before use.
- Emergency procedures in case something goes wrong.

Mobile elevated work platforms (MEWP’s)

MEWPs are powered access machines, used in a huge range of industries. They are a form of lifting device (for people) and as such are subject to any national requirements for inspection and thorough examination (in the UK for example, thorough examinations are required every 6 months).

MEWPs are discussed in detail in section 10.11.

Maintenance, Inspection and Examination

A thorough examination is a systematic and detailed examination of the lifting and all its associated equipment by a competent person. Its aim is to detect any defects which are, or might become, dangerous. A thorough examination may include some *testing* if the competent person considers it to be necessary.

A thorough examination may also be supplemented by *inspection*. Inspections should be carried out at suitable intervals between thorough examinations and may be done ‘in-house’ by a competent, trained employee. Inspections would normally include visual and functional checks, e.g. that lifting wires and jib are free from cracks/damage; safe load indicators are functioning).

A thorough examination should **not** be confused with *preventive maintenance*, although they have some elements in common. Preventive maintenance usually involves replacing worn or damaged parts, topping up fluid levels and making routine adjustments to ensure risks are avoided. Routine maintenance requirements will normally be laid

down by the crane manufacturer. A thorough examination may act as a check that maintenance is being carried out properly but is not intended to replace it.

Some countries lay down specific intervals whereby examinations must be carried out. For example, in the UK examinations must be carried out on goods hoists every 12 months, and on people carriers (such as MEWP's), every 6 months.

Crane operators are usually required to carry out daily visual inspections of their crane (for example, checking for oil leaks, the condition of lifting wires, functioning of safe load indicator/alarms).

Also, cranes should be examined before use for the first time - unless the equipment has an EC Declaration of Conformity less than one-year old and the equipment was not assembled on site. If it was assembled on site, it must be examined by a competent person to ensure that the assembly was completed correctly and safely. In addition, the examination should be carried out after assembly and before use at each location - for equipment that requires assembly or installation before use (e.g. tower cranes).

10.10: Hazards of electricity and static electricity

Electrical Arcing: molten metal splash and radiation

An electric arc is a visible plasma discharge between two electrodes that is caused by electrical current ionizing gasses in the air. Electric arcs occur in nature in the form of lightning.

With proper control, electric arcs can be harnessed and used industrially for welding, plasma cutting and even certain types of lighting such as fluorescent lighting where a high voltage ionizes the inert gas within a glass tube; the flow of current across the ionized gas liberates visible light. However, for every harnessed electric arc there is an unwanted arc. For example, poorly installed (or poor quality) electrical switches, electrical circuit breakers and other electrical contact points are susceptible to these undesired arcs as contacts are opened and closed.

When arcing takes place, ultraviolet radiation is generated. This radiation has the potential to cause severe injuries to the skin and the eye retina. Also, molten metal splashes may occur, causing potentially serious burns to the body (in particular, the eye).

Circumstances giving rise to the generation of static electricity

At its simplest, static electricity is an electrical charge that cannot move. It is created when two objects or materials that have been in contact with each other are separated. When in contact, the surface electrical charges of the objects try to balance each other. This happens by the free flow of electrons (negatively charged particles) from one object to the other. When the objects separate, they are left with either an excess or a shortage of electrons. This causes both objects to become electrically charged.

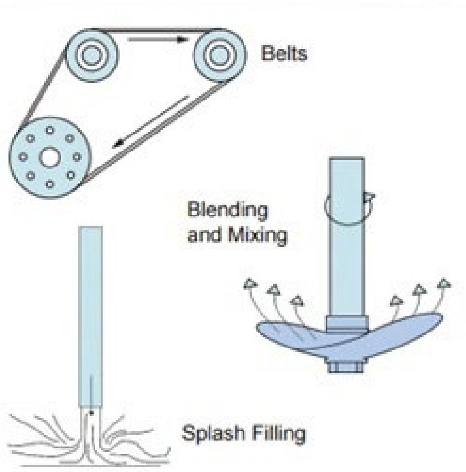
If these charges don't have a path to the ground, they are unable to move and become "*static*". If static electricity is not rapidly eliminated, the charge will build up. It will eventually develop enough energy to jump as a spark to some nearby grounded or less highly charged object to balance the charge. A good example of this in everyday life is lightning. Lightning is produced by a discharge of electricity from one cloud across an air gap to another cloud or between a cloud and the earth.

(Source: http://www.wsps.ca).

Sources of Static Electricity

Static electricity is commonly produced when:

- Liquid flows through a pipe or hose, or through an opening in a pipe or hose
- Spraying or coating
- Blending or mixing
- Filling tanks, drums, cans or pails
- Dry powdered material passes through chutes or pneumatic conveyors
- Non-conductive conveyor belts or drive belts
- Moving appliances are plugged into electrical outlets



People can also accumulate static charges generated by clothing or footwear. This is most likely to happen in dry atmospheres, such as heated buildings in winter, or when walking across carpets and then discharging when touching a metal frame or door.

Hazards of Static Electricity

The main hazard of static electricity is the creation of sparks in an explosive or flammable atmosphere. These sparks can set off an explosion or fire. The danger is greatest when flammable liquids are being poured or transferred.

For static electricity to be a hazard, four conditions must be met:

- There must be a means for a static charge to develop.
- Enough energy must build up to cause ignition.
- There must be a discharge of this energy (a spark).
- The spark must occur in an ignitable vapour or dust mixture.

(Source: http://www.technokontrol.com).

Static Electricity Control Measures

Most static electricity control measures provide ways for the static charges to dissipate harmlessly before sparks occur.

Some ways to prevent static charges from accumulating on materials are:

- Bonding and grounding
- Humidification
- Static collectors
- Additives

Bonding and Grounding

Bonding and grounding (earthing) are common controls for static electricity. Bonding is connecting two or more conductive objects with a conductor, such as a copper wire, that equalises the potential charge between them .

Bonding is also connecting various parts of equipment and containers that are electrically separated by, for example, gaskets or caulking compounds. Note that bonding does not eliminate the static charge.

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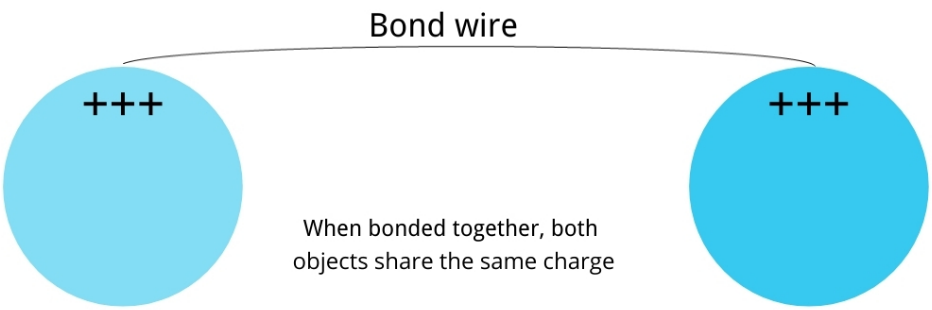


Grounding

Grounding is connecting one or more conductive objects directly to the earth using ground rods, cold water copper pipes, or building steel. Unlike bonding, grounding drains the static charges away as quickly as they are produced.

Static grounds must not be made to electrical conduit systems; plastic pipes; gas or steam pipes; dry pipe sprinkler systems; lightning rods; metal storage racks or building support beams. A designated ground source is preferred.

Connectors for bonding and grounding, such as copper wire and clamps, must provide a good conductive path.

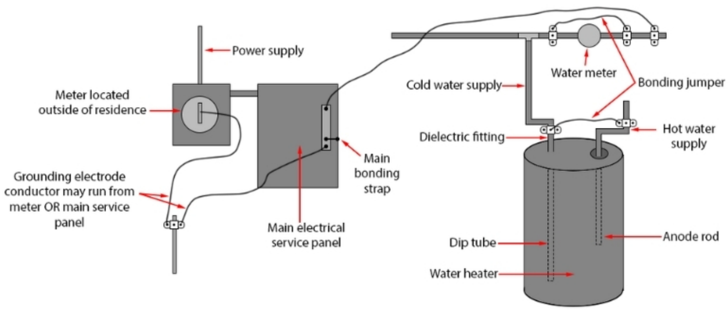
To ensure this:

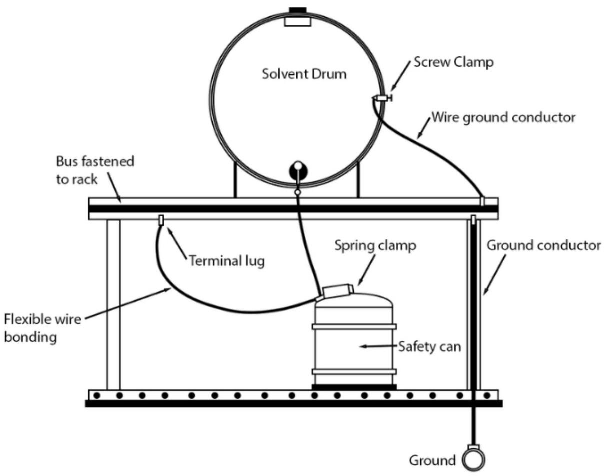
- Remove all dirt, paint, rust, or corrosion from areas where connections are to be made.
- Use connectors that are strong enough for the job.
- Use flexible connectors where there is vibration or continuous movement.
- Connect metal to metal.
- Protect ground clamps and fittings and connectors from physical damage.

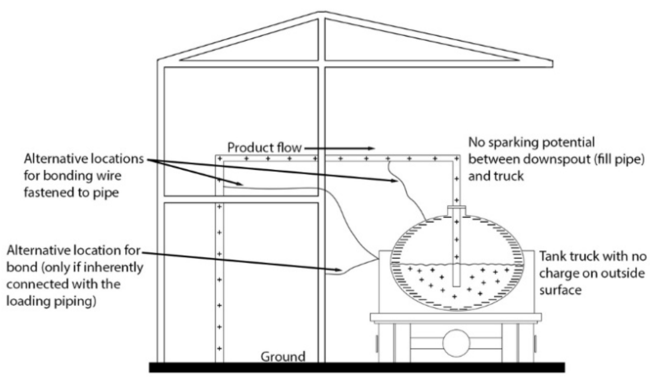
Where liquids are dispensed from their original shipping containers using portable pumps or by gravity through self-closing valves, the pumps or valves must be designed in conformance with good engineering practice. When dispensing flammable liquids, both bonding and grounding are required. Ensure that the receiving container is bonded to the dispensing container before pouring the liquid and that the dispensing container is grounded (see images below).

(Source: http://www.technokontrol.com).

Grounding and Bonding







Humidification
A relative humidity of 60% to 70% at 210°C (700°F) may prevent paper or layers of cloth and fibres from sticking together.

A high relative humidity, however, is no guarantee against the accumulation of static electricity. Therefore, don't rely solely on humidification as a control measure in areas where there are flammable liquids, gases, or dusts.

Static Collectors
Devices that collect static electricity can be used on moving belts, plastic film, and similar nonconductive materials. Some examples of static collectors include: needle pointed copper combs; spring copper brushes; and metallic tinsel bars.

A static collector works by its closeness to the source that generates the static electricity. If a discharge occurs, it is captured by the highly conductive collector; this prevents long hot sparks.

To be effective, collectors must be properly grounded.

Additives
Another control is the use of anti-static additives (as in fuels).

The additive increases the conductivity or lowers the resistance of the liquid.

It also reduces the time it takes for the static charge to leak through the wall of the container and to the ground.

Controlling Static Electricity on People
Controls to prevent or reduce static from building up on people include:

- Conductive flooring.
- Conductive clothing and footwear (to allow the charge to be conducted away; these items must be free of dirt and other contaminants).
- Cotton or linen clothing instead of wool, silk, or synthetic materials.

Control measures for the use of electrical equipment and working on electrical systems

Strength and Capability of Electrical Equipment

The term 'strength and capability' of electrical equipment refers to the ability of the equipment to withstand the thermal, electromagnetic, electrochemical or other effects of the electrical currents which might be expected to flow when the equipment is part of a system.

These currents include, for example, load currents, transient overloads, fault currents, pulses of current and, for alternating current circuits, currents at various power factors and frequencies.
Insulation must be effective to enable the equipment to withstand the applied voltage and any likely transient over-voltages.

A knowledge of the electrical specification and the tests, usually based on the requirements of national or international standards, will assist the user in identifying the withstand properties of the equipment so that it may be selected and installed to comply with this regulation.
Such tests are normally carried out either by the manufacturer or by an accredited testing organisation.

Reducing the risk of shock by using protective systems

Fuses and Circuit Breakers

These devices are designed to break a circuit in the event of a current overload:

- A fuse acts as a weak link in a circuit by melting if the current exceeds the safe limit.
- A circuit breaker is a mechanical device in the form of a switch which automatically opens if the circuit is overloaded.

Both protective devices should be selected so that their rating is above the operating current required by the equipment, but less than the current rating of the cable in the circuit. (For example, if the circuit is designed for less than 1-amp current - such as a desk lamp - a 1-amp protective device should be fitted).

Both devices are primarily designed to protect the circuit and equipment, not the individual.

Reduced Voltage Systems

Where environmental conditions are harsh, such as on construction sites, the use of reduced or low voltages is advisable to reduce the effect of any shock.

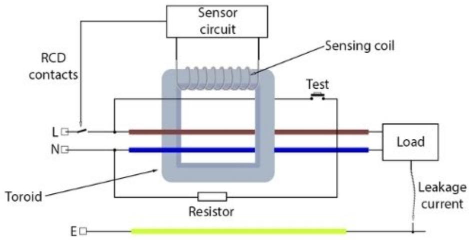
For hand-held portable tools and the smaller transportable units, the 110-volt centre-tapped (CTE) system is typically used. This involves the use of a transformer to reduce the voltage where the public supply is 240v. The system relies on the mid-point of the transformer to be earthed (centre-tapped).

The maximum shock voltage to earth is then half the supply voltage, that is 55 volts in the event of direct contact.

Residual Current Devices

Residual current devices (RCDs) or sensitive current-operated earth leakage circuit breakers (ELCBs) detect when a current flows to earth by comparing the currents flowing in the live and neutral conductors.

They are sensitive enough to detect a leakage current too small to operate a fuse, but which may nevertheless be large enough to deliver an electric shock or to start a fire.
In that event they interrupt the supply by means of automatic circuit breakers. Every RCD has a test button which should be checked regularly to ensure correct operation.

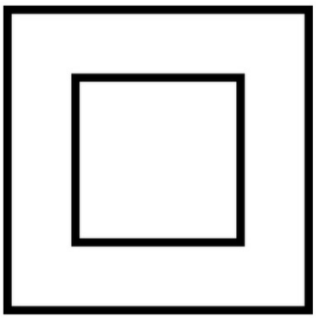


It is important to note that ELCBs only operate when a fault to earth occurs. They do not provide overload protection. They reduce the effects of a shock, not the chances of getting a shock.

Double Insulation

If equipment has a metal enclosure, precautions must be taken to prevent the metalwork from becoming live. This can be achieved by "double-insulation" in which the live parts of the equipment are covered by two layers of insulating material.

Each layer can insulate the live parts alone, but together they ensure that the occurrence of insulation failure and its associated danger is extremely improbable. This method is also suitable for portable equipment which often suffers particularly rough use, but regular maintenance is essential as the insulation only remains effective while it is intact.



Earthing

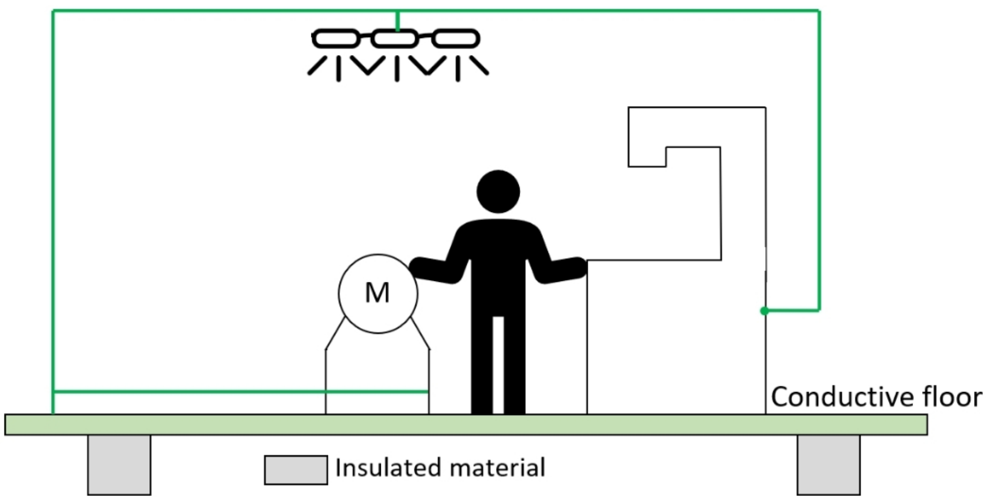
By earthing the exposed metal parts of electrical equipment which should not normally carry a current, any fault current is provided with a low impedance path to earth should it become live.
If all exposed metalwork is properly bonded to earth, it cannot be made live by a fault and the risk of shock is eliminated.

The design and quality of the earth conductor is vital because if it fails, the protection is removed.

Earth-free zones

This is a protective measure that is used in areas where live electrical testing is being carried out.

The principal of operation is, that if the area is insulated from earth (earth free) then even if the live metal is touched there will be no shock because there is no path for the current to flow to earth.



Insulation, Protection and Placing of Conductors

Insulation

The danger to be protected against generally arises from differences in electrical potential (voltage) between circuit conductors or between such conductors and other conductors in a system - usually conductors at earth potential.

The conventional approach is either to insulate the conductors or place them so people are unable to receive an electric shock or burn.

Some form of basic insulation, or physical separation, of conductors in a system is necessary for the system to function.

Factors which must be considered are:

- The nature and severity of the probable danger.
- The functions to be performed by the equipment.
- The location of the equipment, its environment, and the conditions to which it will be subjected.
- Any work which is likely to be done on, with or near the equipment.

Suitable insulation of the conductors in an electrical system is, in the majority of cases, the primary and necessary safeguard to prevent danger from electric shock, either between live conductors or between a live conductor and earth. It will also prevent danger from fire and explosion arising from contact of conductors either with each other or with earth.
Energy from quite low levels of voltage (and levels insufficient to create a shock risk) can ignite a flammable atmosphere. The quality and effectiveness of insulation, therefore, needs to be commensurate with the voltages applied to the conductors and the conditions of use.

Protection

The insulation must be protected as necessary, so that danger may be prevented so far as is reasonably practicable. Often, the protection required is to prevent mechanical damage to the insulation but may include protection against weather, or dusty, corrosive or flammable atmospheres.
Examples of such protection would be the use of steel trunking and conduits, or the use of steel armoured cables.

Placement

Other precautions that may be taken in respect of the conductor include the suitable placing of conductors. They may comprise strictly controlled working practices reinforced by measures such as written instructions, training and warning notices, etc.
The precautions must prevent danger so far as is reasonably practicable.
Examples, where bare conductors are used in conjunction with suitable precautions, are to be found in many applications including overhead electric power lines, down-shop conductors for overhead travelling cranes in factories, etc. railway electrification using either separate conductor and running rails or overhead pick-up wires and certain large electrolytic and electro-thermal plants.

Excess Current Protection

It is recognised that faults and overloads may occur on electrical systems.
Therefore, systems and parts of systems should be protected against the effects of short circuits and overloads if these would result in currents which would otherwise result in danger.
The means of protection is likely to be in the form of fuses or circuit breakers controlled by relays, etc. or it may be provided by some other means capable of interrupting the current or reducing it to a safe value.
(Source: HSE).

Cutting of Supply and Isolation

Where necessary to prevent danger, suitable means are available to switch off the electricity supply to any piece of equipment. Switching can be, for example, by direct manual operation or by indirect operation via ‘stop’ buttons in the control circuits of contactors or circuit breakers.

There should also be available suitable means of ensuring that the supply will remain switched off and inadvertent reconnection prevented. This is isolation. This provision, in conjunction with safe working practices, will enable work to be carried out on electrical equipment without risk of it becoming live during that work.

Suitable isolation should:

- Have the capability to positively establish an air gap or other effective dielectric which, together with adequate creep-age and clearance distances, will ensure that there is no likely way in which the isolation gap can fail electrically.
- Include, where necessary, means directed at preventing unauthorised interference with or improper operation of the equipment, e.g. means of locking off.
- Be located so the accessibility and ease with which it may be employed is appropriate for the application.
- Be clearly marked to show which equipment it relates to, unless there could be no doubt that this would be obvious to any person who may need to operate it.
- Only be common to several items of electrical equipment where it is appropriate for these to be isolated as a group.

In some cases, it may be impracticable to switch off or isolate that equipment which is itself an integral part of a source of electrical energy,(such as the terminals of batteries, battery cells, large capacitors and the windings of generators. In such cases precautions to be taken so that danger is prevented so far as is reasonably practicable. (Source: UK HSE).

Working Space, Access and Lighting

Working space and access

Where there are dangerous exposed live conductors within reach, access and the working space dimensions should be adequate:

- To allow people to pull back away from the conductors without hazard.
- To allow people to pass one another with ease and without hazard.

National standards and guidance may vary slightly with respect to working space (One such standard can be found in Appendix 1 of the UK Electricity at Work Regulations 1989).

Lighting

Natural light is preferable to artificial light, but where artificial light is necessary it is preferable that this be from a permanent and properly designed installation - in indoor switch rooms, etc. However, there will always be exceptions and special circumstances where these principles cannot be achieved, e.g. where hand lamps or torches may be the sole or most important means of lighting.

Inspection and Maintenance Strategy

Organisations should have appropriate systems in place to ensure all aspects of maintenance are carried out.

These which include:

- The Identification of the equipment which must be maintained and when.
- The need for conducting simple user checks for signs of damage - for example, casing, plug pins, cable, and cable sheath.
- Formal visual inspections carried out routinely by a competent person.
- Periodic testing of equipment by a competent person.
- Systems for the reporting and replacement of defective equipment.
- Recording of all maintenance and test results.

National laws (such as the UK Electricity at Work Regulations 1989) is concerned with the need for maintenance to be done to ensure the safety of electrical systems if danger would otherwise result. The quality and frequency of maintenance should be sufficient to prevent danger, so far as is reasonably practicable.
Regular inspection of equipment is an essential part of any preventive maintenance programme. Practical experience of the use of equipment and its environment may indicate an adjustment to the frequency with which preventive maintenance needs to be carried out. This is a matter for the judgement of the organisation. Sufficient Information should be gathered and consulted, including manufacturers guidance, to make an informed decision.

Periodic inspection and testing is required because all electrical installations deteriorate because of factors such as damage, wear, tear, excessive electrical loading, age, and environmental influences. Also, because of modifications or additional loading to the system.

Fixed systems and equipment

The type of inspection and tests which should be carried out, are detailed in the UK Institute of engineering and technology (IET) Wiring Regulations and HSE Guidance Notes. A summary of the main examinations and tests, which may be carried out during periodic inspections follows:

Visual inspection:

- Safety
- Wear and tear
- Corrosion
- Damage
- Excessive loading (overloading)
- Age
- External influences (changes in buildings/occupancy)
- Suitability (e.g. of protective devices)

Periodic tests:

- Verification of effectiveness of earthing system
- Polarity
- Earth fault loop impedance
- Insulation resistance
- Operation of devices for isolation and switching
- Operation of residual current devices and over-current circuit breakers

Guidance on the frequency of inspection of fixed installations is also given in the IET guide. They state that 5 yearly intervals will normally be adequate.

The following specific establishment types are included in the guidance (maximum years between inspection):

- Educational: 5
- Hospitals: 5
- Industrial: 3
- Cinemas/Theatres: 3
- Petrol filling stations: 1
- Temporary installations (e.g. construction sites): 3 months.

Records

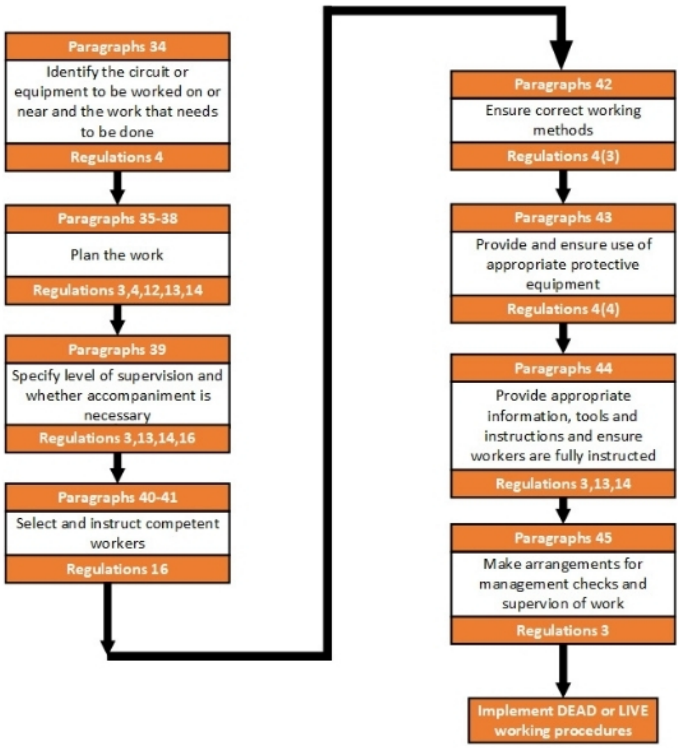
Records of maintenance, including test results, should be kept throughout the working life of the electrical equipment to enable:

- The condition of the equipment to be monitored.
- The effectiveness of the maintenance policies to be assessed.
- The demonstration that an effective maintenance system is in place.
- The duty-holder responsible for the inspection and testing regime to assess the future frequency required between formal visual inspections and any combined inspections and tests.

Safe systems of work on installations made dead

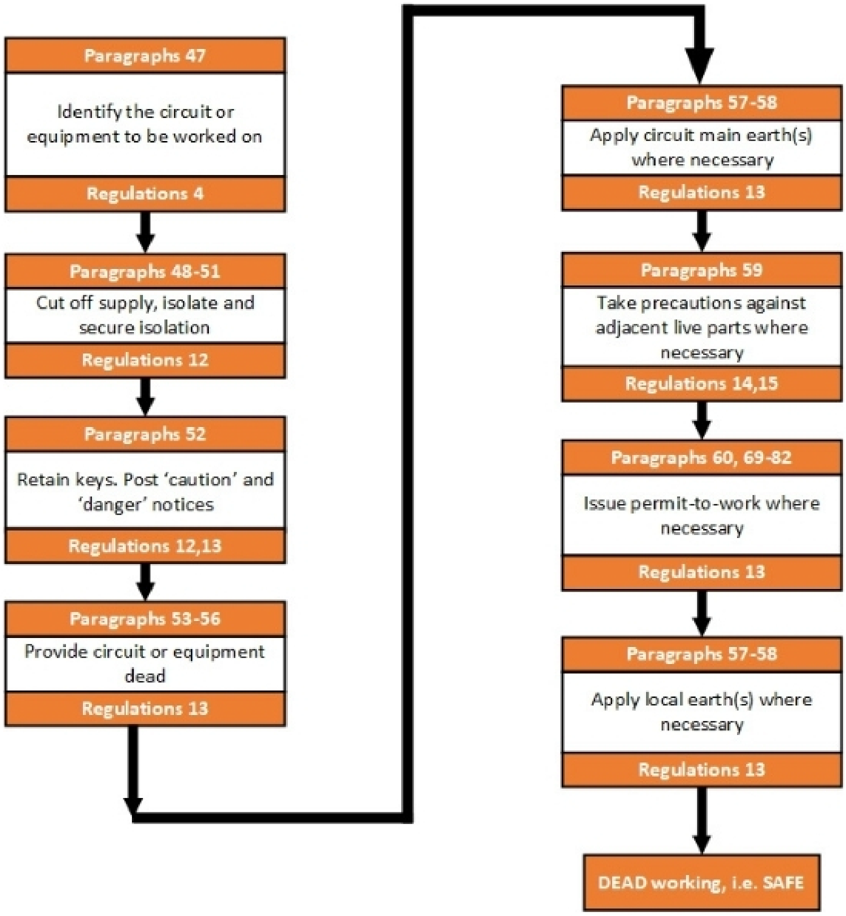
Actions common to both Live and Dead working

The actions common to both dead and live working are illustrated in the image below.



Working dead

While it is not always possible to follow a set procedure rigidly in every situation, the sequence illustrated in the image that follows is recommended as a guide.



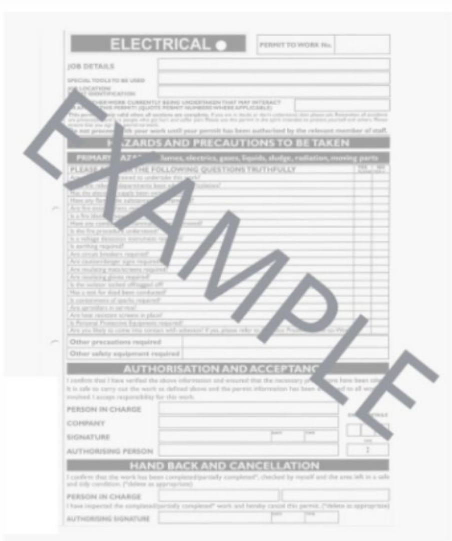
When permits-to-work must be used

An electrical permit-to-work is primarily a statement that a circuit or item of equipment is safe to work on – it has been isolated and, where appropriate, earthed. It is used to confirm which equipment has been made safe, the steps by which this safety has been achieved, and exactly what work is to be done.

An electrical permit-to-work differs to the more general permit-to-work systems used in, for example, the petroleum and chemical industries. These more general permit-to-work systems are an integral part of safety management arrangements covering a wide range of activities and hazards. It is common for the requirement for an electrical permit-to-work to be identified through the application of a general permit-to-work system.

You should not allow anyone to work on equipment that is not specified in the electrical permit-to-work as having been made safe. This restriction should be understood and complied with by everyone in the premises, including directors and senior staff.

If a programme of work must be changed, the existing electrical permit-to-work should be cancelled and a new one issued before any variation is made to the work. The only person who has the authority to agree to the change in programme and issue the new electrical permit-to-work is either the person who issued the original permit or the person nominated by management to take over the responsibility, e.g. at the end of a shift or during absence on leave.



An electrical permit-to-work should be issued by only a designated competent person who has been assessed to be so by means of technical knowledge and/or experience and who is familiar with the system and equipment.

The person should be authorised, in writing, by the employer to issue safety documents such as electrical permits-to-work relating to specified equipment or systems. Before issuing the permit, they should work out, in detail and in writing, what the various steps are to disconnect, isolate, prove dead, lock OFF, earth the equipment, post warning notices, and identify the equipment to be worked on and adjacent equipment which will still be live.

The electrical permit-to-work should state clearly:

- The person the permit is addressed to, i.e. the leader of the group or working party, who will be present throughout the work.
- The exact equipment which has been made dead and its precise location.
- The points of isolation.
- Where the conductors are earthed.
- Where warning notices are posted and special safety locks fitted.

- The nature of the work to be carried out.
- The presence of any other source of hazard, with cross-reference to other relevant permits.
- Further precautions to be taken during the work.

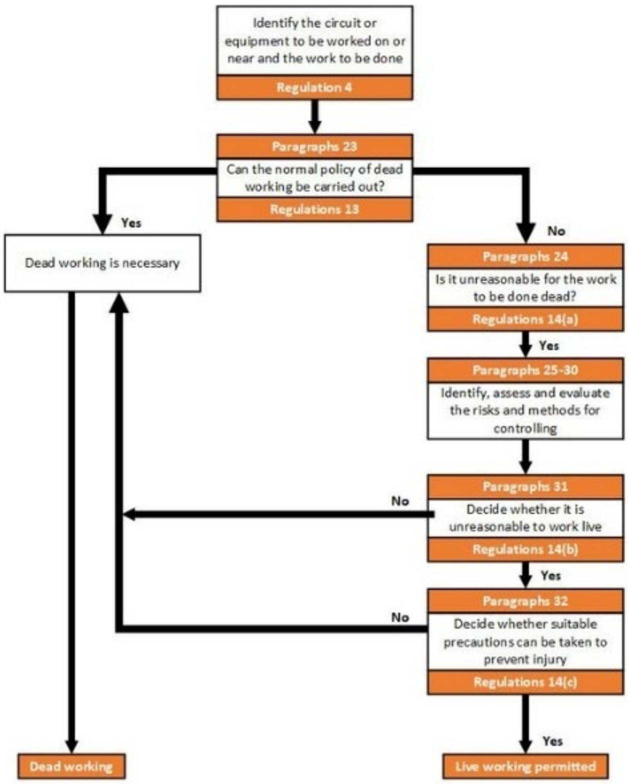
It is strongly recommended that the electrical permit-to-work is issued at the place where the work is being done. The designated competent person issuing the permit should explain the work and agree on the accuracy and completeness of the details with the person doing the work before they both sign the permit. The person issuing the permit must be sure that all necessary action has been taken to make the equipment safe. As a rule, a personal inspection should be made but in geographically very large undertakings, such as the electricity supply industry, it may occasionally be necessary to make an exception to this.

When the work is complete, whoever the permit was issued to should sign it to declare that any additional earths and tools have been removed and people in the group have been withdrawn and instructed not to approach the equipment again. The person clearing the permit should also indicate whether the equipment is fit for service. The permit is then returned, preferably to the designated competent person who originally issued it, for cancellation before the equipment is re-energised.

(Source: HSE)

Safe systems of work and criteria of acceptability for live working

Providing the requirements in the image below have been met, live working can still only be justified if suitable precautions are taken to prevent injury arising from the hazards identified in the risk assessment.



The precautions should have been identified in the risk assessment and might include:

- Installing temporary insulation, protective enclosures, or screens to prevent parts at different potentials being touched at the same time.
- Using temporary barriers with warning notices affixed to keep unauthorised people away from the work area.
- Making sure that workers understand the task and the system to be worked on, (clarity of instructions is essential), are trained and experienced and follow the correct procedures.
- They must be competent to realise their own limitations and know when to seek help.
- Providing lighting and working space that is adequate and free from trip hazards.
- Using robust and properly insulated tools.
- Using test instruments with insulated probes and fused leads.
- Maintaining tools and test equipment in good condition and replacing them if damaged.
- Avoiding lone live working.
- Providing and using correct personal protective equipment (PPE) to reduce the risk of contact with live parts or earth, e.g. insulating gloves, insulating matting.

High voltage systems

Common high voltage systems and the prevention of danger

High voltage circuits are those with more than 1000 V for alternating current and at least 1500 V for direct current. (In the United States 2005 National Electrical Code (NEC), high voltage is any voltage over 600 V).

High-voltage direct current (HVDC) is used to transmit large amounts of power over long distances or for interconnections between asynchronous grids. When electrical energy is to be transmitted over very long distances, the power lost in AC transmission becomes appreciable and it is less expensive to use direct current instead of alternating current.

For a very long transmission line, these lower losses (and reduced construction cost of a DC line) can offset the additional cost of the required converter stations at each end.

HVDC is also used for submarine cables (cables below the surface of the water) because AC cannot be supplied over distances of more than about 30 kilometres because the cables produce too much reactive power.

In these cases, special, high-voltage cables for DC are used. Submarine HVDC systems are often used to connect the electricity grids of islands, for example, between Great Britain and continental Europe, between Great Britain and Ireland, between Tasmania and the Australian mainland, and between the North and South Islands of New Zealand. Submarine connections up to 600 kilometres (370 mi) in length are presently in use.

Electricity is transmitted at high voltages (115 kV or above) to reduce the energy loss which occurs in long-distance transmission. Power is usually transmitted through *overhead power lines*. Underground power transmission has a significantly higher installation cost and greater operational limitations, but reduced maintenance costs. Underground transmission is sometimes used in urban areas or environmentally sensitive locations.

Electric transmission networks are interconnected into regional, national, and even continent-wide networks to reduce the risk of such a failure by providing multiple redundant, alternative routes for power to flow should such shutdowns occur. Transmission companies determine the maximum reliable capacity of each line (ordinarily less than its physical or thermal limit) to ensure that spare capacity is available in the event of a failure in another part of the network.

Additional precautions for High-Voltage Work

High-voltage equipment should be designed and installed so that it is not necessary to work on exposed live parts. However, it is commonly necessary for voltage checks or tests to be carried out, and for observations to be made from safe distances such as when carrying out phase rotation tests.

Because high voltages can arc across an air gap, you can suffer a shock or burn without touching live voltage parts. The dead working procedure (shown in a flow chart earlier) must therefore be followed. Isolation should be by means of a device that has a safe isolating gap between live parts and those that have been made dead for work to be carried out. Earthing conductors at the point where the supply is disconnected are essential and additional earths may be necessary at the place of work.

The system of locking OFF while work is in progress should use safety locks which have unique keys so that the apparatus cannot be inadvertently re-energised. The keys should be retained in a key safe or other suitable place available only to the person in charge of the activity.

The precautions should be backed up with a disciplined documentation system; the *electrical permit-to work* is an established system that has been proved to work well in practice and was described earlier.

Precautions must be taken to prevent people approaching dangerously close to un-insulated high-voltage conductors. This will normally mean that any work on high-voltage equipment is undertaken only after precautions such as disconnection, secure isolation and proving dead have been taken. There are, however, some special situations where, using appropriate tools, apparatus, and precautions, work on live high-voltage conductors may be permissible while the people involved are at a safe distance. Two examples are work on overhead conductors by distribution network operators, or work on railways using long, specially designed, insulated tools. The precautions listed earlier for "working live" should also be adopted.

Safe Working Near Overhead Power Lines

Introduction

Every year people at work are killed or seriously injured when they come into contact with live overhead electricity power lines. These incidents often involve:

- Machinery, e.g. cranes, lorry-loader cranes, combine harvesters, and tipping trailers
- Equipment, e.g. scaffold tubes and ladders
- Work activities, e.g. loading, unloading, lifting, spraying, and stacking

If a machine, scaffold tube, ladder, or even a jet of water touches or gets too close to an overhead wire, then electricity will be conducted to earth. This can cause a fire or explosion and electric shock and burn injuries to anyone touching the machine or equipment. An overhead wire does not need to be touched to cause serious injury or death as electricity can jump, or arc, across air gaps.

UK HSE guidance note "*GS6: Avoiding danger from overhead power lines*" offers advice on safe working practices that can be adopted to avoid danger.

Types and Heights of Overhead Power Lines

Most overhead lines have wires supported on metal towers/pylons or wooden poles - they are often called ‘transmission lines’ or ‘distribution lines’.

Most high-voltage overhead lines, i.e. greater than 1000 V (1000 V = 1 kV) have wires that are bare and un-insulated, but some have wires with a light plastic covering or coating. All high-voltage lines should be treated as though they are un-insulated.

There is a legal national minimum height for overhead lines laid down, which varies according to the voltage carried. Generally, the higher the voltage, the higher the wires will need to be above ground (see Figure that follows).

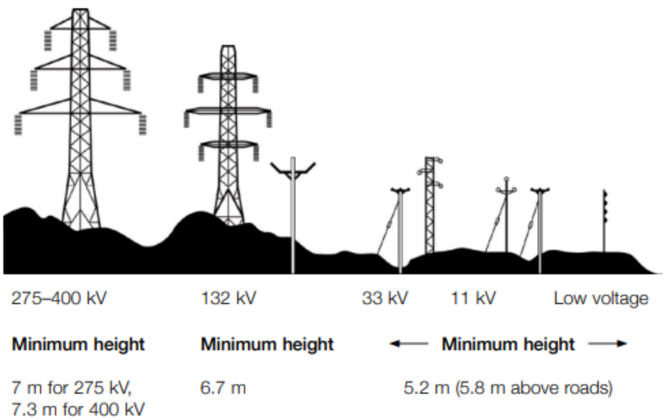


Figure 4 Minimum heights above ground level for overhead power lines

Preventing Overhead Line Contact Accidents

If you cannot avoid working near an overhead line and there is a risk of contact or close approach to the wires, you should consult its owner to find out if the line can be permanently diverted away from the work area or replaced with underground cables. This will often be inappropriate for infrequent, short-duration or transitory work.

If this cannot be done and there remains a risk of contact or close approach to the wires, find out if the overhead line can be temporarily switched off while the work is being done.

If the overhead line cannot be diverted or switched off, and there is no alternative to carrying out the work near it, you will need to think about how the work can be done safely. If it cannot be done safely, it should not be done at all. Your site-specific risk assessment will inform the decision.

Things to consider as part of your risk assessment include:

- The voltage and height above ground of the wires. Their height should be measured by a suitably trained person using non-contact measuring devices.
- The nature of the work and whether it will be carried out close to or underneath the overhead line, including whether access is needed underneath the wires.
- The size and reach of any machinery or equipment to be used near the overhead line.
- The safe clearance distance needed between the wires and the machinery or equipment and any structures being erected. If in any doubt, the overhead line's owner will be able to advise you on safe clearance distances.
- The site conditions, e.g. undulating terrain may affect stability of plant, etc.
- The competence, supervision and training of people working at the site.

Working Near but Not Underneath Overhead Lines – Use of Barriers

Where there will be no work or passage of machinery or equipment under the line, you can reduce the risk of accidental contact by erecting ground-level barriers to establish a safety zone to keep people and machinery away from the wires. This area should not be used to store materials or machinery. Suitable barriers can be constructed out of large steel drums filled with rubble, concrete blocks, wire fence earthed at both ends, or earth banks marked with posts.

- If steel drums are used, highlight them by painting them with, for example, red and white horizontal stripes.
- If a wire fence is used, put red and white flags on the fence wire.
- Make sure the barriers can be seen at night, perhaps by using white or fluorescent paint or attaching reflective strips.

Passing Underneath Overhead Lines

If equipment or machinery capable of breaching the safety clearance distance must pass underneath the overhead line, you will need to create a passageway through the barriers, as illustrated below.

In this situation:

- Keep the number of passageways to a minimum.
- Define the route of the passageway using fences and erect goalposts at each end to act as gateways using a rigid, non-conducting material, e.g. timber or plastic pipe, for the goalposts, highlighted with, for example, red and white stripes.
- If the passageway is too wide to be spanned by a rigid non-conducting goalpost, you may have to use tensioned steel wire, earthed at each end, or plastic ropes with bunting attached. These should be positioned further away from the overhead line to prevent them being stretched and the safety clearances being reduced by plant moving towards the line.
- Ensure the surface of the passageway is levelled, formed-up and well maintained to prevent undue tilting or bouncing of the equipment.
- Put warning notices at either side of the passageway, on or near the goalposts and on approaches to the crossing giving the crossbar clearance height and instructing drivers to lower jibs, booms, tipper bodies etc. and to keep below this height while crossing.
- You may need to illuminate the notices and crossbar at night, or in poor weather conditions, to make sure they are visible.
- Make sure that the barriers and goalposts are maintained.
- On a construction site, the use of goalpost-controlled crossing points will generally apply to all plant movements under the overhead line.

Figure 5 Typical passageway through barriers

Working Underneath Overhead Lines

Where work must be carried out close to or underneath overhead lines, e.g. road works, pipe laying, grass cutting, farming, and erection of structures, and there is no risk of accidental contact or safe clearance distances being breached, no further precautionary measures are required.

If you cannot avoid transitory or short-duration, ground-level work where there is a risk of contact from, for example, the upward movement of cranes or tipper trailers or people carrying tools and equipment, you should carefully assess the risks and precautionary measures. Find out if the overhead line can be switched off for the duration of the work.

If this cannot be done:

- Refer to organisations such as the Energy Networks Association (ENA), whose publication Look Out Look Up! A Guide to the Safe Use of Mechanical Plant in the Vicinity of Electricity Overhead Lines. This advises establishing exclusion zones around the line and any other equipment that may be fitted to the pole or pylon. The minimum extent of these zones varies according to the voltage of the line, as follows:

Low-voltage line - 1 m

11 kV and 33 kV lines - 3 m

132 kV line - 6 m

275 kV and 400 kV lines - 7 m

- Under no circumstances must any part of plant or equipment such as ladders, poles and hand tools be able to encroach within these zones. Allow for uncertainty in measuring the distances and for the possibility of unexpected movement of the equipment due, for example, to wind conditions.
- Carry long objects horizontally and close to the ground and position vehicles so that no part can reach into the exclusion zone, even when fully extended.
- Machinery such as cranes and excavators should be modified by adding physical restraints to prevent them reaching into the exclusion zone. Note that insulating guards and/or proximity warning devices fitted to the plant without other safety precautions are not adequate protection on their own.
- Make sure that workers, including any contractors, understand the risks and are provided with instructions about the risk prevention measures.
- Arrange for the work to be directly supervised by someone who is familiar with the risks and can make sure that the required safety precautions are observed.
- If you are in any doubt about the use of exclusion zones or how to interpret the ENA document, you should consult the owner of the overhead line.
- Where buildings or structures are to be erected close to or underneath an overhead line, the risk of contact is increased because of the higher likelihood of safety clearances being breached. This applies to the erection of permanent structures and temporary ones such as tents, marquees, flagpoles, rugby posts and telescopic aerials. In many respects these temporary structures pose a higher risk because the work frequently involves manipulating long conducting objects by hand.

Emergency Procedures

If someone or something comes into contact with an overhead line, it is important that everyone involved knows what action to take to reduce the risk of anyone sustaining an electric shock or burn injuries.

Key points are:

- Never touch the overhead line's wires.
- Assume that the wires are live, even if they are not arcing or sparking, or if they otherwise appear to be dead.
- Remember that, even if lines are dead, they may be switched back on either automatically after a few seconds or remotely after a few minutes or even hours if the line's owner is not aware that their line has been damaged.

- If you can, call the emergency services. Give them your location, tell them what has happened and that electricity wires are involved, and ask them to contact the line's owner.
- If you are in contact with, or close to, a damaged wire, move away as quickly as possible and stay away until the line's owner advises that the situation has been made safe.
- If you are in a vehicle that has touched a wire, either stay in the vehicle or, if you need to get out, jump out of it as far as you can. Do not touch the vehicle while standing on the ground. Do not return to the vehicle until it has been confirmed that it is safe to do so.

Portable electrical equipment

Why portable electrical equipment could be more of a risk than static equipment

Conditions and practices likely to lead to accidents

Nearly a quarter of all reportable electrical accidents involve portable equipment. Most of these accidents result in electric shock, with the next most common result being fires.

The conditions and practices likely to lead to these problems are:

- **Using equipment in inappropriate conditions** - Most particularly where cables are liable to be damaged in use and/or where there is water present. For example, using an electric powered pressure water cleaner outside, where the trailing cable may be damaged by vehicles and other equipment, and live wires exposed in a wet environment. In offices, the leads from floor cleaners are often exposed to damage where they trail across corridors and through doors.
- **Using damaged equipment** - Cracked or scoured plugs; split cables; damage to equipment casing - either from a failure to carry out routine maintenance checks and repairs or continuing to use equipment after it has been damaged. This is a problem on construction sites where the harsh operating conditions mean there is a high probability of mechanical damage and often many people use the same piece of equipment with few if any checks.
- **Broken connections to the appliance; inadequate earthing** - Often because of poor maintenance regime.

Electrical risks from portable appliances

Portable Generators
Portable generators are often used when there is no fixed electrical supply system easily available (such as remote construction sites) or when there is more power needed than is available locally.

The main means of protection against electrical shock should be by using a well-maintained generator which is correctly installed and adequately earthed. This affects the safety of the whole installation, so it should only be installed by someone who is competent to do so.

It should not be possible to connect the generator(s) in parallel with the public supply system unless written agreement has been reached with the electricity supplier.

The electricity supplier will set out the arrangements necessary for you to ensure a safe connection. If there is more than one generator and they are to be operated in parallel, the system should be designed so that the load is shared between them.

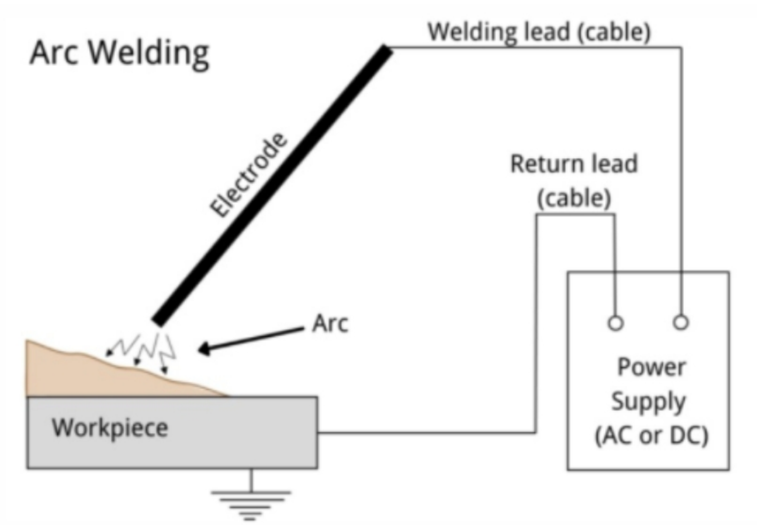
Unless the generator is supplying only double insulated equipment within a few metres of itself, there is a risk that a fault in the equipment, the cables or the generator could cause the equipment casing to become live without blowing the fuse or tripping any circuit breakers. To avoid this, one point (usually the neutral or star point) of the generator output circuit should be earthed, and bonded to the structural steelwork of the building and any scaffolding, etc. which may carry electrical equipment.

At outdoor venues earthing should be by earth rods.

Electric Welding Sets
The arc welding process requires a live electrical circuit. This means that all arc welders using hand held equipment will be at risk of electric shock and electrical burns. The risk for MIG/MAG and TIG welding is much less as the welding current is normally switched on and off using the trigger or foot switch.

For all arc welding processes, the essentials of safe practice are:

- Welding equipment conforms to the appropriate international (ISO) or British (BS) standards.
- Installation of fixed welding equipment is carried out by a suitably qualified person and is connected as recommended by the manufacturer.
- The insulation on the welding and current return leads is undamaged and the conductor is thick enough to carry the current safely.
- All connectors are clean, undamaged and correctly rated for the current required.
- Don't use welding equipment with damaged insulation on the welding cables, plugs, clamps or torch/electrode holder.
- Use the appropriate personal protective equipment for the task.



Stray welding currents
For most welding operations, it is better to clamp the current return cable close to where you are welding.

Stray welding currents are electrical currents that return to the welding set by paths other than along the welding return cable.

Stray currents may be substantial and comparable to the welding current resulting in a risk of electric shock, burns, and damage to property.

Stray currents are more likely if the welding return path exhibits a high electrical resistance e.g. the return is clamped onto a rusty surface rather than clean metal.

When welding on large structures and pipe work installations clamping the welding return to handrails, pipes or the frame of the structure should be avoided unless they form part of the work piece itself.

Some older Manual metal arc (MMA) welding sets are built specifically to use an earth return cable that is shared between several welding sets.

This type of equipment was common in the shipbuilding and ship repair industry. This type of welding set up should only use equipment that is designed to be used this way.

The current return path should be as short as possible and may need to be carefully planned to ensure risk is minimised.

Welding in Environments with an Increased Risk of Electric Shock

For operations where there is a need to:

- Weld in damp or wet conditions.
- Position the welder inside a metal structure e.g. inside a tank.
- Position the welder on the metal work piece.

An insulating mat or some other dry platform may need to be provided, so welders are not in direct contact with wet or conductive surfaces.

Often a wooden pallet or rubber floor mat will suffice. The mat should be large enough to offer protection to the welder if they are required to kneel or lie down to complete the task.

Welders should wear clean, dry welding gloves and overalls. Overalls or other clothing should be worn to minimise the amount of naked skin, particularly on arms and legs.

When MMA welding it is better to use a welding set that has an open circuit voltage (no load voltage) limiting device. These devices reduce the risk of electric shock from inadvertent contact with the electrode.

Control Measures for the Safe Use of Portable Electrical Equipment

Introduction

Portable electrical equipment can cause an electric shock or burn, or fire due to damage, wear, or misuse. UK HSE guidance note "HSG 107: Maintaining portable electrical equipment" outlines maintenance plans for most electrical portable equipment (such as drills, grinders, pressure washers, electric kettles, computers) used in all environments. The maintenance plans outlined are based on a straightforward, inexpensive system of user checks, formal visual inspection, and testing.

User Checks
The person utilising the electrical equipment should be encouraged to look at it critically and, after a minimum of

basic training, check (before use and periodically when in use) visually for signs that the equipment is not in sound condition.

For example:

- Damage to the cable.
- Damage to the plug - for example, the casing is cracked, or the pins are bent, heat scorch marks.
- Inadequate joints, including taped cable joints.
- The outer sheath of the cable is not effectively secured where it enters the plug or the equipment.
- The equipment has been subjected to conditions for which it is not suitable - for example, it is wet.
- Damage to the external casing of the equipment, such as cracks.

User checks should also include extension leads when used, and associated plugs and sockets.

Any faults should be reported, and the equipment taken out of use immediately. Effective action should be taken to ensure that the equipment is not used again until repaired by a person competent to carry out the task.

Formal Inspection and Tests
Organisations should have in place systems for the formal inspections of electrical equipment and installations. This should include:

- **Routine visual inspections** carried out by a competent person to control immediate risks and monitor the user checks. These will be visual checks similar to those discussed above but undertaken in a more formal and systematic manner.
- **Periodic combined inspections** and tests again carried out by a competent person. Such inspections and tests may also be required in situations where there is reason to think that the equipment may have a fault.

Any equipment found to be faulty should be taken out of service and not used again until properly repaired.

Combined inspection and testing should be carried out by someone with a higher level of competence than that required for visual inspection alone, because the results of the tests may call for interpretation and appropriate electrical knowledge will be essential. However, the same worker can often carry out both types of inspection.

Routine Visual Inspections
Regular visual inspections are generally the most important part of a maintenance regime and most (potentially dangerous) faults can be detected in this way.

Simple written guidance relating to the visual inspection can be produced, summarising what to look for and procedures to follow when problems are found. It can assist the person carrying out the formal visual inspection and users of the equipment.

The formal visual inspection should not include taking the equipment apart. This should be confined, where necessary, to the combined inspection and testing discussed below. However, additional checks could include removing the plug cover and checking that a fuse is being used (for example, it is a fuse, not a piece of wire, a nail, etc.), the cord grip is effective, the cable terminations are secure and correct, including an earth where appropriate, and there is no sign of internal damage, overheating or presence of liquid or foreign matter. Checks may also be made to ensure that there is no evidence of overheating (burn marks or staining) and that the correct rating for the fuse and the correct cable rating is being used (to prevent overloading).

The inspections should be carried out at regular intervals. The period between inspections can vary considerably depending on the type of equipment, the conditions of use and the environment. For example, equipment used on a construction site fabrication workshop will need much more frequent inspection than such equipment as computers in an office. In all cases, however, the period between inspections should be reviewed in the light of experience.

Combined Inspection and Tests

The checks and inspections outlined above will, if carried out properly, reveal most (potentially dangerous) faults. However, some deterioration of the cable, its terminals, and the equipment itself can be expected after significant use, for example, a broken earth wire within a flexible cable, deterioration of insulation quality or contamination of internal and external surfaces. Additionally, equipment may show signs of being misused or abused to an extent which may give rise to danger.

Inspection and testing are the only reliable ways of detecting such faults and should be carried out on a regular basis to back up the inspection regime. The regularity will depend on the type of equipment, the manner and frequency of use and the environment. In addition, other occasions when testing is likely to be justified are:

- Whenever there is reason to suppose the equipment may be defective, but this cannot be confirmed by visual inspection alone.
- After any repair, modification, or similar work.

Testing is often carried out at two levels, demanding different levels of competence from the person carrying out the task:

- Simple "pass/fail" types of test where no interpretation of readings is necessary. Providing the appropriate test procedures are rigorously followed and acceptance criteria are clearly defined, the routine can be straightforward.
- The use of more advanced test instruments which give readings that require interpretation. This requires technical knowledge or experience and specific electrical skills.

The inspection carried out in conjunction with the testing should usually include checks for:

- Correct fusing.
- Effective termination of cables and cores.
- Suitability of the equipment for its environment.

Frequency of Inspection and Testing

If there are no specific legal requirements in your country, deciding on the frequency of maintenance is a matter of judgement and should be based on an assessment of risk factors.

These include:

- Type of equipment and whether it is hand-held.
- Manufacturer's recommendations.
- Initial integrity and soundness.
- Age of the equipment.
- Working environment in which the equipment is used and the likelihood of mechanical damage.
- Frequency of use.
- Foreseeable abuse of the equipment.

- Analysis of previous records of maintenance.

Records of Inspection and Testing
A suitable log is useful as a management tool for monitoring and reviewing the effectiveness of the maintenance scheme and to demonstrate that a scheme exists. It can also be used as an inventory of equipment and a check on the use of unauthorised equipment (e.g. domestic kettles or electric heaters brought to work by employees).

The log can include faults found during inspection, which may be a useful indicator of places of use, or types of equipment, that are subject to a higher-than-average level of wear or damage. This will help monitor whether suitable equipment has been selected. Entries in a test log can also highlight any adverse trends in test readings that may affect the safety of the equipment, thus enabling remedial action to be taken. Be careful when interpreting trends where a subsequent test may be done with a different instrument from that used for an earlier test, as differences in the results may be due to difference in the instruments rather than deterioration in the equipment being tested.

Records do not necessarily have to be on a paper system. Test instruments are available that store the data electronically, which can then be downloaded directly onto a computer database.

Organisations with large amounts of equipment will find it useful to label equipment to indicate that the equipment has been tested satisfactorily i.e. has been passed as safe, and when the date for the next test is due. Otherwise, individual items may be missed on consecutive occasions.

Portable Appliance Testing (PAT)
Portable appliance testing (PAT) is the term used to describe the examination of electrical appliances and equipment to ensure they are safe to use. Most electrical safety defects can be found by visual examination, but some types of defect can only be found by testing.

However, it is essential to understand that visual examination is an essential part of the process because some types of electrical safety defect cannot be detected by testing alone.

PAT normally involves A visual inspection checking for:

- Damaged flexes
- Damaged plugs and equipment (overheating, burn marks, discolouration)
- Correctly wired plugs
- Correctly rated fuse

Then a series of tests (depending on the class of equipment), that may include:

- Earth continuity testing
- Insulation resistance
- Polarity test
- Earth leakage test

Issues relating to aspects of supply to portable electrical equipment

Portable electrical equipment is often supplied by power cables (unless battery operated).

If the cable runs along the floor it can be damaged in several ways:

- Run over by vehicles.
- Abrasion from contact with the floor.
- Contact with dust, corrosive material, sharps.
- Contact with hot surfaces (such as pipes).
- A potential trip hazard.

The best solution, when in use outside and where practicable, is to run the supply cable overhead and out of harm's way. This removes both the potential electric shock (from a damaged cable) problem and trip hazard. Where this cannot be done the use of industrial cable cover protectors should be considered.

If inside, careful design of socket placement can reduce the risk of damage and trips. Alternatively, the use of cable covers should be considered. For 240v supplied equipment (such as supplies to floor cleaners) an RCD should be used. There are several types of RCD that can be used to protect from electric shock:

Fixed RCDs: these are installed in the fuse box and can provide protection to individual or groups of circuits. A fixed RCD offers the highest level of protection as it protects all the wiring and the sockets on a circuit, and any connected appliances.

Socket-Outlet RCDs: these are special socket-outlets with an RCD built into them which can be used in place of a standard socket-outlet. This type of RCD provides protection only to the person in contact with equipment, including its lead, plugged into the special socket-outlet.

Portable RCDs: these plug into any standard socket-outlet. An appliance can then be plugged into the RCD. They are useful when neither fixed nor socket-outlet RCDs are available but, as with socket-outlet RCDs, they provide protection only to the person in contact with the equipment, including its lead, plugged into the portable RCD.

10.11: Construction (including Work at Height, Demolition and Excavation work)

What is construction

Introduction

Construction is the process of constructing a building or infrastructure. It differs from manufacturing in that manufacturing typically involves mass production of similar items without a designated purchaser, while construction typically takes place on location for a known client. Construction as an industry comprises six to nine percent of the gross domestic product of developed countries. It starts with planning, design, and financing; and continues until the project is built and ready for use.

Large-scale construction requires collaboration across multiple disciplines. For the successful execution of a project, effective planning is essential. Those involved in the design and execution of the infrastructure in question must consider zoning requirements, the environmental impact of the job, the successful scheduling, budgeting, construction-site safety, availability and transportation of building materials, logistics, inconvenience to the public caused by construction delays and bidding.

In general, there are three sectors of construction: buildings, infrastructure and industrial. Building construction is usually further divided into residential and non-residential (commercial/institutional). Infrastructure is often called heavy/highway, heavy civil or heavy engineering. It includes large public works, dams, bridges, highways, water/wastewater, and utility distribution. Industrial includes refineries, process chemical, power generation, mills and manufacturing plants.

The health and safety professional's role in construction projects

The Health and Safety professionals' role in construction projects can take many forms. Predominantly, they will be responsible for advising on the Health and Safety risks during construction projects in conjunction with the site management.. They may be involved in pre-start meetings before projects begin and as such may get involved in the H&S requirements before works begin. This may involve the checking of Safe systems of work or Risk Assessments and method statements, ensuring that they are appropriate for the project. They may also have to notify statutory authorities that works are taking place.

They may also need to consider things such as welfare arrangements, access to site, any risks with overhead and underground services and dealing with the management of excavations.

During the course of the project, they are likely to attend regular construction progress meetings where H&S is an agenda item. H&S risks on construction sites are very high and ensuring standards are maintained are critical.

There may also be a role for them in terms of assisting in delivering any induction training or Toolbox Talks in conjunction with the Site Manager particularly if the construction project is to do with the organisation that the Health and Safety Professional is working in.

Finally, they may also be involved in pulling together any H&S requirements at the end of the project, such as information about services that have been installed, how certain equipment works and should be maintained (such as lifts) and ensuring that this is passed onto the end user.

Types of work

Building Works

Building construction is the process of adding structure to property or construction of buildings. Most of building construction jobs are small renovations, such as the addition of a room, or renovation of a bathroom. The large works often involve a cross section of trades within the construction industry, such as joiners, brick layers, painters, plumbers and steel erectors.

Renovation (also called *remodelling*) is the process of improving a broken, damaged, or outdated structure. Renovations are typically either commercial or residential.

Alteration works involve changing the layout of an existing building or structure when it no longer suits the use for which it was originally intended.

Maintenance of Existing Premises

Preventative maintenance keeps up a building's appearance and extends its life. It also prevents the loss of original fabric, as less material is lost in regular, minimal and small-scale work than in extensive restoration projects.

Preventative maintenance makes economic sense as it may reduce or potentially eliminate the need for, and the extent of, major repair projects. Repairs can be disruptive and costly in terms of fabric and finances, so extending the period between repair campaigns by carrying out maintenance places less of a burden on community resources. A small but regular investment in tasks such as the routine cleaning of gutters and drains can be much cheaper and less inconvenient than having to cope with a serious outbreak of dry rot in timber roof trusses following years of neglect.

If premises are occupied, careful planning is required to ensure the health and safety of occupants during maintenance work. For example, exposing them to hazards such as dust, falling debris, noise and moving vehicles. This may occasionally mean carrying out work outside normal working hours.

Unoccupied premises pose special risks. Unoccupied premises are an inescapable factor in the commercial property market and arise anywhere in town and city centres, and industrial estates. Un-occupancy may be long or short term and often occurs prior to sale or refurbishment. Fires starting in unoccupied premises feature prominently in UK loss statistics. Causes of fire are mainly arson-related, but also include electrical faults in fixed/damaged wiring. In addition, water damage to empty buildings is a high-risk due to inadequate maintenance, especially when routine site inspections are not carried out. The hazards presented by unoccupied buildings need to be adequately risk assessed prior to any maintenance work.

Civil Engineering and Works of Engineering Construction

Civil engineering is a professional engineering discipline that deals with the design, construction, and maintenance of the physical and naturally built environment, including works like roads, bridges, canals, dams, and buildings. Civil engineering is traditionally broken into several sub-disciplines, such as groundworks, joinery, painting, and plumbing.

Engineering construction covers the spectrum of activities that make up the construction industry.

ILO Convention C167 (Safety and Health in construction) defines work of (engineering) construction as:

- Building, including excavation and the construction, structural alteration, renovation, repair, maintenance (including cleaning and painting) and demolition of all types of buildings or structures.
- Civil engineering, including excavation and the construction, structural alteration, repair, maintenance and demolition of, for example, airports, docks, harbours, inland waterways, dams, river and avalanche and sea

defence works, roads and highways, railways, bridges, tunnels, viaducts and works related to the provision of services such as communications, drainage, sewerage, water and energy supplies.

- The erection and dismantling of prefabricated buildings and structures, as well as the manufacturing of prefabricated elements on the construction site.

Demolition

Demolition is the tearing-down of buildings and other structures. (it contrasts with deconstruction or dismantling, which usually involves taking a building apart while carefully preserving valuable elements for re-use.)

The Range of Construction Activities

Site Clearance

Site clearance consists of preparing the site prior to the works being undertaken. This may involve removal of hazardous waste, obstructive trees, unwanted scrub, and landscaping. Demolition activities may also be required as part of site clearance prior to construction works beginning. Where there are high levels of contaminants, it may also be necessary for ground remediation.

Following completion of construction works, site clearance will involve removal of all waste associated with the construction activities (e.g., brick and timber cut-offs, packaging, spoil) to a licensed waste disposal site. It will also include the removal of all plant and equipment used on the construction with the aim of leaving the site in a clean and tidy state ready for its intended use.

Considerations to be made when clearing a site include:

- The history of the site and its usage
- The risks to operatives from handling or disturbing materials and substances
- The means by which waste and spoil from a site clearance can be transported and disposed of
- Survey of land contamination
- Nature conservation

Demolition and Dismantling

Some construction activities require the removal of building or structures prior to the commencement of new builds. Dismantling involves careful removal of components for further use, whilst demolition means destructive removal of a structure or building. Both types of activity must be carefully planned and carried out in a way that prevents danger by practitioners with the relevant skills, knowledge, and experience.

Key issues include:

- Falls from height
- Injury from falling materials
- Uncontrolled collapse
- Risks from connected services
- Traffic management
- Hazardous materials
- Noise and vibration
- Fire

Excavation

Excavation work generally means work involving the removal of soil or rock from a site to form an open face, hole or cavity using tools, machinery, or explosives. It includes earthwork, trenching, wall shafts, tunnelling and underground. Excavation is used in construction to create building foundations, reservoirs, and roads. Some of the different processes used in excavation include trenching, digging, dredging and site development. Each of these processes requires unique techniques, tools, and machinery to get the job done right. The processes used will depend upon the structure that will result from the construction process.

Unloading and Storage of Materials

A construction site, especially a large one, is usually a hive of activity with people and machinery moving around. This inevitably increases the chances of an accident or incident occurring.

One significant safety issue comes from the delivery and subsequent loading or unloading of items to the site, whether it be delivering materials and equipment or removing waste.

To start with, deliveries or removals should be planned so that traffic in and around the construction site is minimised to as great an extent as is possible. If there is little space available or partially blocked roadways, the large trucks may have to perform manoeuvres such as reversing around corners where it is difficult to see structures or people that may be in the roadway. This greatly increases the chances of causing death or serious injury to a person.

If possible, loading or unloading should take place in a clearly marked designated area, away from other site operations, so that the chances of encountering other people is minimised.

As well as the moving vehicles, there is also a hazard from the material during the unloading process and from its storage. In serious cases such as when large, heavy items are being moved by cranes or lifting equipment, there is the risk of fatalities or serious/permanent injury if goods are not properly secured. There is also the danger of manual handling injuries occurring to workers who are unloading or manually transporting the items to where they will be stored or moving them around the site.

It needs to be ensured that items which are stacked are stable and will not fall on top of somebody who happens to be walking below.

Stored items should not block or obstruct routes of escape that will be needed in the event of an emergency such as a fire. Whilst this may be less of an issue if it is kept in a dedicated storage area, sometimes material is placed in other areas, particularly if it is going to be used soon.

The type of material being stored also needs to be considered. If it is hazardous, it may require specific precautions and control measures such as bunds for toxic substances or keeping separate from other substances to prevent a reaction.

Site Movements

Each year within the construction industry in the UK, approximately ten people die because of being struck by moving plant. In addition, there are hundreds of preventable accidents and injuries.

Planning a safe site should begin before the construction phase.

Principal contractors should ensure that pedestrians and vehicles are adequately separated by establishing:

- Pedestrian-only areas from which vehicles are completely excluded.

- Safe designated pedestrian routes to work locations.
- Vehicle-only areas, especially where space is limited, or traffic is heavy and
- Safe vehicle routes around the site.

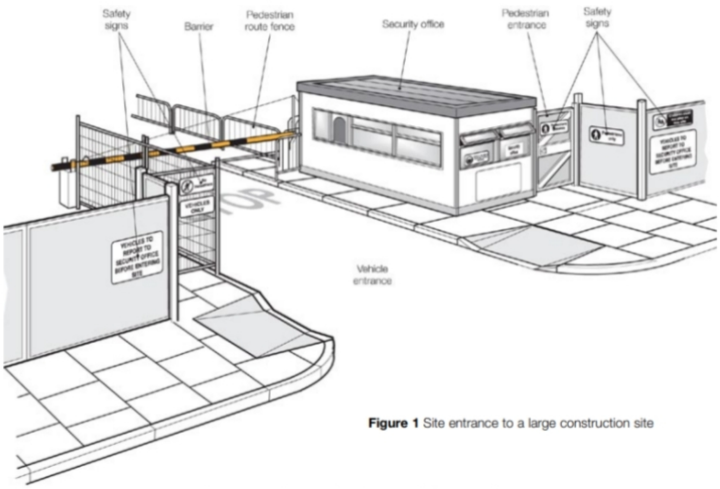


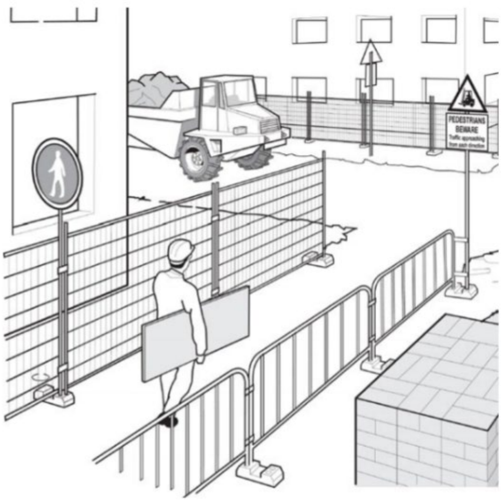
Figure 1 Site entrance to a large construction site

https://www.hse.gov.uk/pUbns/priced/hsg144.pdf

Pedestrian routes should be established on site which provide safe pedestrian access to work areas.

Pedestrian routes should be either located a safe distance away from areas of vehicle activity or provided with appropriate physical protection, such as substantial fencing and/or kerbs, to prevent pedestrians being struck by vehicles or their loads.

At points where large numbers of pedestrian's cross busy vehicle routes, e.g., near site welfare facilities, appropriate traffic control measures should be implemented, such as designated pedestrian crossing points and traffic control systems. Vehicle movements around the site can be restricted to specified times.



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In some circumstances it may not be reasonably practicable to achieve physical segregation between pedestrians and vehicles, e.g., during infrequent, short duration, low risk unloading operations. In such cases signallers/banksmen and safe systems of work should be used to control vehicle and pedestrian movements.

On site, vehicle routes should be established which:

- Are segregated from pedestrian routes
- Minimise the need for reversing operations with one-way systems and turning points
- Are adequate for the number, type and size of the largest vehicles that may use them
- Have firm surfaces, adequate drainage, and safe profiles to allow safe vehicle movements
- Are kept clear of obstructions and other hazards
- Avoid steep gradients and tight bends where practicable
- Avoid hazards such as excavations, edges of structures, and fuel or chemical storage areas
- Have the minimum necessary number of junctions
- Are clearly signed with signposts and, where appropriate, road markings (e.g., on concrete or tarmac roads) showing the right of way, etc.
- Have speed limits and speed control measures specific to site conditions and the types of vehicles using the route, e.g., some lift trucks may be unsuitable for passing over road humps
- Keep site vehicles, delivery vehicles and private vehicles apart, where possible, by establishing private vehicle parking areas, specified delivery routes and storage areas

Fabrication, Decoration and Cleaning

While a significant amount of fabrication takes place off site in the preparation of building or structural erection (for example, steelwork, large vessels) there will still be a need for onsite work, either in a dedicated workshop area or on the site itself. This can include steel erecting, welding and form working.

During on site fabrication, activities may involve working at height and the use of specialist equipment such as welding machines, nail guns (which use explosive cartridges) and hydraulic wrenches, all of which may pose a risk to the users and others nearby.

Once the main building work has been carried out on a site, the task of decoration starts. This consists of applying coatings of a varied nature to create a final finished appearance for a building or structure.

Decoration is often required both outside and in, with paint, wallpaper, cement renders, artex and plaster used. The chemical effects of the various substances used needs to be considered when devising control measures for avoiding their harmful effects. Again, the potential risks when working at height need to be considered.

Construction work will inevitably produce large quantities of dirt, dust and general debris, and this means that surfaces both inside and out will require cleaning on a regular basis. This will involve applying water, steam or various abrasive or chemical agents to the surfaces to be treated, which can include walls, windows, floors, fabric, plant, and roadways.

To apply cleaning agents or to carry out cleaning procedures, various methods of application are used. These can be as simple as a scrubbing brush or broom, or as involved as high-pressure blasting jets. Those operating the cleaning equipment should be trained to use it and should be required to demonstrate their competency before starting work.

It is also the case that cleaning activities take place at all levels of a construction site and remedial and maintenance work may mean that workers must ascend to the tops of buildings and structures to carry out these activities, so again work at height is an issue that needs to be considered.

Installation, Removal and Maintenance of Surfaces

Various utility services (such as electricity, gas/water pipelines, telecommunications) are required, or may need to be removed, on both existing and new construction sites and are almost always buried underground. In new installations, a great deal of liaison is required with the planning authority, utility companies and designer concerning the route the services will take. The work will often involve excavation with heavy plant and the loading and unloading of materials.

It is often the case that new services are connected to their source outside the construction site boundary. This can mean that the public is at risk and the site plan needs to address the requirement for suitable means of traffic control (e.g., signs and lighting) guarding and protection of the public (barriers and warning signs).

Landscaping

During the final stages of a construction project, once the main work has been concluded, landscaping usually takes place. It can be classified as either:

Hard Landscaping: Hard landscaping refers to all the structure within a garden or grounds and does not include the plants. Hard landscaping most often refers to the boundaries such as walls and fencing, and is inclusive of pathways, walls, decking, paving and patios.

Soft Landscaping: Soft landscaping is pretty much, the exact opposite of hard landscaping in that now it only involves plants and vegetation and involves no real construction work.

The following are some of the tasks that landscapers may be involved in:

- Coordinating planting of shrubs, turf
- Paving
- Building retaining walls
- Constructing decking/pergolas
- Setting out landscape works
- Building landscape features with concrete, timber, brick, stone, and metal
- Installing irrigation and drainage

Particular construction issues

The transitory nature of workers

The organisation of labour in the construction industry is fundamentally different from most worksites. Construction projects may take weeks, months, or years. During this time, groups of trades people come and go from the job site as their skills are needed. This differs from most industrial sites where a constant group of employees work together over a longer period of time. Workers in the industry are accustomed to travelling on completion of a project great distances to secure work in other areas. Getting worker buy in and commitment to health and safety is not always easy, particularly if moving from a large, well-managed project to a small, less well managed project.

There is also the issue therefore of ensuring regular Health and Safety training and Toolbox Talks to ensure key Health and Safety risks are communicated to the transitory workforce. There will almost certainly be a large migrant workforce making up the construction workforce and therefore Health and Safety Information will need to be appropriately communicated.

The Temporary Nature of Construction and the Constantly Changing Workplace

The very nature of a construction means that things are constantly changing. The layout of the site may be different from one day to the next, with structures and hazards appearing and disappearing as the work progresses. This can create its own dangers as it can lead to disorientation and confusion; causing people and vehicles to not only enter areas where they should not be, but also meaning that they could be so busy trying to find where they need to go that they will not be paying full attention to the numerous other dangers present on site. Therefore it is imperative that Health and Safety information is communicated and refreshed on a regular basis to ensure that the dangers ever present on site are made aware to the workforce.

Fire Arrangements

Many solids, liquids and gases used in construction (such as wood, fuel, LPG) can catch fire and burn. It only takes a source of ignition, which may be a small flame or an electrical spark, together with air. Any outbreak of fire threatens the health and safety of those on site and will be costly in damage and delay. It can also be a hazard to people in surrounding properties. Fire can be a hazard in refurbishment work when there is a lot of dry timber and at the later stages of building jobs where flammable materials such as adhesives, insulating materials and soft furnishings are present.

Many fires can be avoided by careful planning and control of work activities. Good housekeeping and site tidiness are important not only to prevent fire, but also to ensure that emergency routes do not become obstructed. Making site rules can help.

Actions that can be taken to prevent fire include:

- Use less-easily ignited and fewer flammable materials, e.g., use water-based or low-solvent adhesives and paint
- Keep the quantity of flammables at the workplace to a minimum
- Always keep and carry flammable liquids in suitable closed containers

To minimise the risk of gas leaks and fires involving gas-fired plant:

- Close valves on gas cylinders when not in use
- Regularly check hoses for wear and leaks
- Prevent oil or grease coming into contact with oxygen cylinder valves
- Do not leave bitumen boilers unattended when alight
- Store flammable solids, liquids, and gases safely. Separate them from each other and from oxygen cylinders or oxidising materials. Keep them in ventilated secure stores or an outdoor storage area. Do not store them in or under occupied work areas or where they could obstruct or endanger escape routes.
- Have an extinguisher to hand when doing hot work such as welding or using a disc cutter that produces sparks.

Check the site periodically to see that all plant and equipment that could cause a fire is turned off. Stop hot working an hour before people go home, as this will allow more time for smouldering fires to be identified:

- Provide closed metal containers to collect rubbish and remove them from the site regularly.
- Collect highly flammable waste such as solvent-soaked rags separately in closed fire-resisting containers.

Emergency procedures should be in place in the event of a fire breaking out. They should include provision for:

- Means of warning
- Means of escape
- Means of fighting fire

Time Pressures from Clients

One of the biggest (if not the biggest) influences on the way that a job is carried out and therefore the health and safety of those working on it is the client. Written into a contract may well be bonuses for early completion and penalties for delays. In a highly competitive industry such as construction, the pressures are often strong on contractors to get the job done as fast as they can.

Even in Europe and the United States, these are very real concerns for contractors and in countries where the regulatory framework is not so strong, there is little incentive to move at a pace that facilitates safe working practices.

The decisions made by the client, who is often hostage to schedules beyond his control, have substantial influence on the time, money, and other resources available for the project. It is because of this, and the degree to which pressure may be brought to bear on contractors, with the commensurate risks this may cause, that in the UK the Construction Design and Management Regulations make the client accountable for the impact their decisions have on health and safety.

Although time pressures are very real, there can be situations where clients want to handback some areas of construction sites and as long as this can be managed in a safe way, this can have a positive impact.

Weather Conditions

For those working outdoors, such as construction workers, adverse weather can cause a variety of problems.

Short term exposure to the sun can cause excessive sweating, dehydration, and fatigue. There are fears that prolonged exposure can cause skin cancer. This is a particular problem in hot countries such as Dubai, where major construction projects have been carried out in recent years where efforts to persuade construction workers to cover up exposed skin have met with cultural resistance.

Heavy rain may cause soft ground conditions which can increase problems with site traffic and undermine the stability of scaffolds and excavations. In addition it can cause issues for trucks being able to access sites. UK sites suffer from this but in tropical countries, monsoon rains may well bring sites to a halt for weeks at a time and structural reassessment of conditions may have to be undertaken afterwards.

Extreme cold leads to snow and ice which increases the likelihood of slips and falls, and additional loading on structures such as scaffolds. It can also lead to soft ground conditions once the snow has melted and may also increase the risk of brittle failure of equipment. Sites in colder parts of the world (such as the USA and Russia) will

have to cope with this on a regular basis but with the change in climate conditions, countries such as the UK that may not be prepared for extended periods of cold weather may have to consider ways in which they can make provision for the added risks that this may cause.

Levels of Numeracy and Literacy of Workers

Poor levels of literacy and numeracy can significantly impede progress of workers in Construction (or indeed any other workplace). The level of understanding and critical information retention required, for example, while attending a health and safety induction can be significantly reduced.

Where numbers and the written word are utilised instead of a pictographic approach, the meaning can be impaired regarding written critical safety instructions. Directions that may need to be followed, such as instructions on a piece of machinery or a warning on a container of chemicals could be unintentionally ignored. Weights, measures, dates, and times critical to processes could also be misconstrued if workers are innumerate.

Workers who do not speak the native language

Essential health and safety information, instruction and training form a significant part of a safe system of work in any industry, but none more so than construction.

For years in the middle east Construction workforces have been massively subsidised by migrant workers, in Europe similarly with the free movement of people. Therefore, at any one time, a sizeable proportion of the labour force on a UK construction site may be non-national and consideration needs to be given to the difficulties that can arise when different languages are involved.

It is essential that all workers understand critical health and safety information.

Ways of achieving this for migrant workers include:

- Delivering an induction course in several languages to suit the workforce
- Ensuring that migrant contractors have a supervisor with a basic understanding of the relevant national language
- Using a ‘buddy system’ - putting experienced workers with new or inexperienced migrant workers who speak the same language to help smooth the transition when they are first taken on
- Using nonverbal communication to get the message across for example, DVDs or videos, audio tapes, and/or internationally recognised pictographic signs and symbols

General health and safety duties for construction projects

The relevance of site layout; access and egress; protection of the public

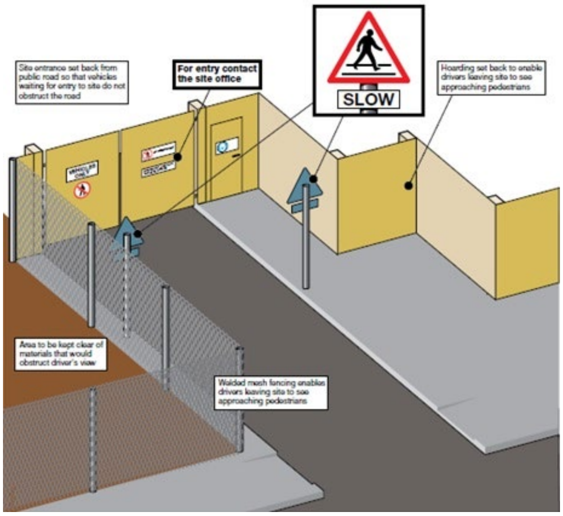
(Site layout; access and egress; protection of the public as noted by the UK HSE publication HSG150)

Access and egress

There should be safe access onto and around the site for people and vehicles. Plan how vehicles will be kept clear of pedestrians, especially at site entrances where it may be necessary to provide doors or gates to achieve this segregation. Doors that open onto traffic routes may need viewing panels or windows.

The health and safety plan should include how vehicles can be kept clear of pedestrians at vehicle loading/unloading areas, parking and manoeuvring places, and areas where drivers’ vision may be obstructed.

For some large construction projects it may be beneficial to have a security gatehouse to manage traffic and visitors on site and also to prevent unauthorised access.

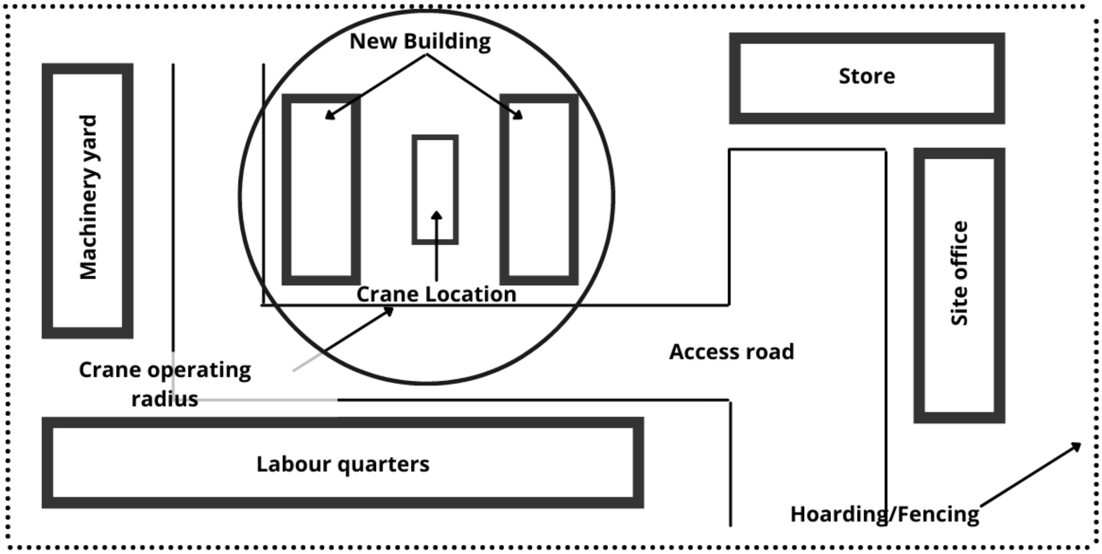


Site layout and protection of the public

Construction work should be fenced off and suitably signed. This will protect people (especially children) from site dangers and the site from vandalism and theft.

For some jobs, the workplace will have to be shared. Perhaps the work will be done in an operating factory or office. Agree who must control each area. Agree what fences, barriers, means of separation or permits to work are required to keep both construction workers away from hazards created by others and other people away from hazards created by the construction work; site rules might be needed.

Make sure there is a system to ensure necessary precautions are kept in place during working hours and that night-time and weekend protection is put in place as required before the site closes.



The Use of Method Statements and Permits-to-work

Method statements

Method statements are widely used in construction as a means of controlling specific health and safety risks that have been identified (perhaps following the preparation of a risk assessment) such as; lifting operations, demolition or dismantling, working in confined spaces, asbestos removal, steel and form work erection.

The process of preparing a written method statement should provide evidence that:

- Significant health and safety risks have been identified.
- Safe, coordinated systems of work have been put in place.
- Workers have been involved in the process.

Where they are prepared, method statements need to be no longer than is necessary for them to be effective. They are for the benefit of those carrying out the work and so should be clear, should not be overcomplicated and may be illustrated where necessary. It is good practice also to provide Toolbox Talks to construction workers to convey the key message of any method statements.

Activity:		Contractor:	
Person completing this statement:		Tel: ( )	
Date:		Contract number:	

Key steps	Equipment or plant required	Possible hazards	Safety controls including personal protective equipment (PPE)	Licences, qualifications or work permits
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				

Permits to work.

A Permit to Work is used to cover high risk, non-routine activities (such as entry into confined spaces and hot work). Whilst it is a key part of a safe system of work in industries such as oil and gas and chemical industries, where working on plant and equipment that have contained flammable or toxic materials is commonplace, it may also be used in the construction industry for works such as confined space entry, work on electrical systems, excavations and any other task where a permit is deemed necessary by the site authority.

Risk assessments and Method statements are key control documents used on construction sites so it is important that Permits if used, are only used for activities where they will add value. Several different control documents do not necessarily mean that an activity will be safe, as it may be perceived as just a "paper" exercise

General duties on construction projects

The ILO code of practice “safety and health in construction” lays down duties for employers working on construction projects (an employer may be considered to employers employing one or more workers on a construction site – in effect the principal contractor and he other contractor companies working on the project).

It’s important to determine a chain of command for communication on a construction project. These are typically spelled out in the contract documents and usually require the client, designer and the principal contractor to communicate with each other throughout the project. In turn, the principal contractor is usually responsible for communicating information to the contractors and subcontractors. This in particular includes information contained in any health and safety plan, usually prepared by the principal contractor, or scope changes which can affect health and safety. Any changes should be comprehensive and communicated in a timely fashion.

Consultation is also a key requirement of the ILO code of practice. That is, ensuring that workers have an input into the decision-making processes that may affect their health and safety. On a construction project this may be achieved by setting up a health and safety committee/site progress meeting consisting of worker and management representatives from each of the participating contractor companies.

The code of practice also requires workers to report to their immediate supervisor, and to the workers' safety representative where one exists, any situation which they believe could present a risk and which they cannot properly deal with themselves.

Protecting workers and others before and during construction work

The application of design risk management (DRM) at design phase and how residual risk should be handled

The purpose of DRM is to control or limit design-related uncertainty in order to prevent harm coming to those involved in all aspects of the lifecycle of a structure.

The designer has to consider all those whose health and safety may be affected by the design not just during construction but also in the commissioning, operation or use, repair and maintenance, decommissioning and finally demolition of the structure.

Examples of the type of situations that the designer may consider include:

- Alternative traffic flows during repairs by providing removable barriers
- Emergency access for repairs in the event of a component failure
- He means of cleaning windows in a multi-story structure
- The need for access in extreme weather conditions

Having identified a significant health and safety threat, the first option for a designer is to design out, or eliminate, the risk.

This, of course, is not always possible. The designer should then detail the actions that are necessary to control foreseeable risks that could not be eliminated or have their impact reduced through design (For example, provision of a fixed steel access ladder, with cage guard, on a tall vessel leading to an intermediate landing platform.

What needs to be considered if the site has access/egress points on a public road

The thing that needs to be considered when the site has access/egress on a public road, is first and foremost, appropriate signage. Members of the public need to be aware that there is a live construction site and appropriate warnings put in place

Other factors to be considered include the use of mirrors, situated in suitable positions, so workers leaving the construction site are aware of pedestrians and vehicles.

If construction vehicles need a large turning circle or the vehicles need to reverse out of a construction site onto a public road, then a banksman should be put into place to safely guide the vehicle out onto the public road and at the same time stop any vehicles on the public road so the construction vehicle can leave the site safely.

If the site is operating over a long period of time, there may need to be liaison with the local highway authorities to look at what additional measures may need to be put in to place to ensure safe movement of vehicles to and from the site.

Site Security

For most construction sites, the perimeter fence defines the area within which construction work is being carried out. Ensuring that this fencing is in place and is robust is a key control for the protection of the public.

Fencing should have proper signage to warn of the potential hazards inside and occasionally inspected to check for damage.

Additionally, good access control and possibly site security presence should help to control who enters the site - that includes the presence of possible arsonists intent on causing damage to the site, or persons intent on theft.

Specific construction hazards such as deep excavation, access ladders to scaffolding, construction machinery (such as dumpers or excavators) are an attractive proposition for children, and therefore must be properly managed.

Specific steps that should be taken to ensure child safety include:

- Secure sites adequately when finishing work for the day
- Barrier off or cover over excavations and pits
- Isolate and immobilise vehicles and plant and if possible lock them in a compound
- Store building materials (such as pipes, manhole rings, and cement bags) so that they cannot topple or roll over
- Remove access ladders from excavations and scaffolds
- Lock away hazardous substances

To satisfy the curiosity of the public (and particularly children) who are often intrigued by construction sites, the installation of strategically placed "viewing points" in the perimeter fence can help to satisfy public curiosity and not expose them to hazards within the site.

On some projects, hazards can be created outside the perimeter fence, for example, wagons removing soil from the site spreading mud on roads around the site. The problem can be solved by installing a simple mud cleaning facility on the site as part of layout planning.

Arrangements

Site Rules

Clients may insist on certain safety precautions, especially where their business continues at the premises while construction work is in progress. It may assist everyone if site rules are applied. Site rules might cover, for example, the use of personal protective equipment, traffic management systems, pedestrian routes, site tidiness, fire prevention, emergency procedures or permit-to-work systems or they may be working in live environments so may have to work around members of the public.

It should be made clear to all workers where the site rules apply, and the client premises rules are, and where they apply.

Shared Facilities

Occupied premises will usually have welfare facilities such as toilets, drinking water, hot/cold water and rest facilities plentifully available for their own employees. If it can be agreed with the premises controller (e.g. a Client) and if the facilities are sufficient in number, to share the facilities with contractors (this is particularly the case with toilet and hot/cold water facilities.)

However, on large projects, this is unlikely to work. The responsibility, therefore, normally falls on the Main (or Principal) contractor to ensure that sufficient facilities are available for the numbers of contractors likely to be working on the site.

Welfare Facilities

The ILO " Safety and health in construction" C167 require that:

- "At or within reasonable access of every construction site an adequate supply of wholesome drinking water shall be provided.
- At or within reasonable access of every construction site, the following facilities shall, depending on the number of workers and the duration of the work, be provided and maintained:
- Sanitary and washing facilities;
- Facilities for changing and for the storage and drying of clothing;
- Accommodation for taking meals and for taking shelter during interruption of work due to adverse weather conditions.
- Men and women workers should be provided with separate sanitary and washing facilities."

The UK HSE states that.

"Everyone who works on any site must have:

- Access to adequate toilet and washing facilities.
- A place for preparing and consuming refreshments
- Somewhere for storing and drying clothing and personal protective equipment.

The following sections cover what welfare facilities the UK HSE states should be in place:

“If mobile teams work at many locations over a few days (e.g. road repair and cable-laying gangs), these facilities can be provided at a central location accessible within a reasonable distance or time. Alternatively, "mobile" facilities may be provided”.

Toilets

Toilets should be suitable and sufficient, ventilated, lit and kept in a clean and orderly condition.

Washing facilities must be provided so that workers can use them immediately after using the toilet or urinal, even if they are provided elsewhere.

Washing facilities

General washing facilities must be suitable and sufficient, kept clean and orderly and with basins or sinks large enough for people to wash their face, hands, and forearms.

The facilities should include:

- Clean hot and cold, or warm, running water
- Soap or other suitable means of cleaning
- Towels or other suitable means of drying
- Showers where the nature of work is particularly dirty or there is a need to decontaminate

Drinking water

Drinking water must be provided or made available at readily accessible and suitable places.

Cups are required unless the supply is in a jet from which people can drink easily.

Changing rooms and lockers

Changing rooms are needed where workers must wear special clothing for the purposes of their work and cannot be expected to change elsewhere.

The rooms must be provided with seating, means of drying and keeping clothing and personal effects secure".

Facilities for rest

Rest rooms or rest areas are required equipped with tables and seating (with backs) sufficient for the number of persons likely to use them at any one time.

There should be arrangements for meals to be prepared and eaten, plus means for boiling water. In cold weather, heating should be provided.

Arrangements for Site Inductions

The principal contractor must ensure every site worker is given a suitable site induction. The induction should be site specific and highlight any risks and control measures that those working on the project need to know about.

The following issues should be considered:

- Senior management commitment to health and safety
- Outline of the project
- Management of the project
- First-aid arrangements
- Accident and incident reporting arrangements
- Arrangements for briefing workers on an ongoing basis, e.g. toolbox talks
- Arrangements for consulting the workforce on health and safety matters
- Individual worker's responsibility for health and safety

The HSE states *"Site inductions should also be provided to those who do not regularly work on the site, but who visit it on an occasional (e.g. architects) or once-only basis (e.g. students). The inductions should be proportional to the*

nature of the visit. Inductions provided to escorted visitors need not have the detail that unescorted visitors should have.

Escorted visitors only need to be made aware of the main hazards they may be exposed to and the control measures".

Work at height

The hazards and risks associated with working at height

Introduction

Working at height remains one of the biggest causes of fatalities and major injuries. Common causes include falls from ladders and through fragile surfaces.

'Work at height' means work in any place where, if there were no precautions in place, a person could fall a distance liable to cause personal injury (for example a fall through a fragile roof).

The main risks when working at height are:

The worker falling from height: The biggest cause of fatalities in the workplace, and responsible for a large percentage of major injuries, such as permanent disability injuries including paralysis, and multiple fractures.

Falling objects from height: causing fractures, brain damage, and even fatality.

An example of construction activities which involve working at height include:

- Scaffolders erecting or dismantling a scaffold
- Roofers installing, replacing or repairing a pitched or flat roof
- Steel erectors installing the framework of a building or structure
- Painters coating a structure or a building
- Joiners erecting formwork

Many of these tasks will involve the use of some sort of access or fall prevention/protection equipment.

Figure 13 Access system for short-term maintenance work on a fragile roof

Types of access and work at height equipment

Mobile Elevated Work Platforms

Introduction

Mobile elevated work platforms (MEWPs) are powered access machines, used in a huge range of industries. They are available in two basic types: boom (cherry pickers) and vertical (scissor lifts). Boom lifts have two types of operation, static or mobile.

An MEWP saves time and makes work at height efficient, effective and safer than using traditional methods of access. When used safely, MEWPs significantly reduce the risk of injuries through falling from height.

It is important that those responsible for selecting, specifying and managing MEWPs on site (the competent person) understand the risks associated with the use of a MEWP so they can advise on the precautions required to eliminate or control those risks. Planning is crucial to their safe operation.

There are many different types of MEWP with various rated capacities, working heights, and outreaches. Before deciding which type of MEWP is the most suitable for the job.

The following should be considered:

- What work needs to be done?
- At what stage in the job will the MEWP be needed and what will the ground conditions or supporting structure be like at that stage (i.e. rough, prepared, poured slab, finished surface, etc.)?
- What access is there onto the site to deliver/collect a MEWP and to travel it to and from the work location?
- What terrain and gradient will the MEWP have to cross to get to the work position and is operator visibility and segregation adequate for the manoeuvre?
- Are there any overhead power lines or subterranean hazards on site to be avoided?
- How much space is available to position and operate the MEWP at the work position?
- What is the maximum ground bearing capacity at the work area and along the route to and from the work positions?
- How many people need to be lifted?
- What is the required safe working load (SWL) of the machine?
- What height and outreach are required?
- Will the MEWP be expected to move in the elevated position?
- Are there likely to be any overhead structures that the operator could be crushed against?
- Are there any materials to be lifted and if so what is their weight/shape/length?
- Are material handling devices required?

Once the most suitable type and size of MEWP for the job has been chosen, the hazards associated with its use need to be considered, the risks assessed, and control measures identified to develop a safe working method.

Scissor Lifts

Scissor lifts are large mobile vertical lifts (sometimes called ‘flying carpets’). Ideal for use in a variety of applications in both indoor and outdoor spaces, where a straight lift is required for access.

Although narrow width models are available, usually scissor lifts would not be suitable for tighter spaces as they offer a much larger platform area for workers. They are also available as rough terrain versions and with double extending decks.

Articulated Booms

Articulated boom lifts, most often referred to as a cherry picker, offer an extensive range of movement.

The sideways outreach makes it a practical solution for both indoor and outdoor applications, as the extended reach enables the platform to manoeuvre around and over obstacles such as buildings and other equipment.

Available in a range of sizes, with additional features including rough terrain option, non-marking tyres and a variety of power options.

Truck Mounted Booms.

Truck mounted access lifts, also called lorry mounted platforms, are the perfect solution for multi-location projects, as they can travel between sites quickly and be ready to use immediately upon arrival.

They offer exceptional height capabilities, as well as side reach, making them ideal outdoor applications and tasks.

Hazards associated with MEWPs

According to the UK HSE the most fatal and serious injuries involving MEWPs arise from:

- **Entrapment:** Operator trapped between part of the basket and a fixed structure, e.g. when manoeuvring in confined overhead areas of steelwork. Operators may become trapped against the platform controls, and if this happens they may not be able to stop the machine running.
- **Overturning:** The machine may overturn throwing the operator from the basket
- **Falling:** An operator may fall from the basket during work activities
- **Collision:** The vehicle may collide with pedestrians, overhead cables or nearby vehicles

These hazards should be identified within a risk assessment and suitable control measures put in place.

Controlling the risks associated with MEWPs

There are several precautions that can reduce the risk from MEWP hazards. These are:

- **Confined overhead working**: Brief operators on the dangers, and the safe system of work to be followed. If there are overhead structures against which an operator could be trapped and then pushed onto the MEWP

controls, consider selecting a MEWP that has been designed to prevent such accidental contact. MEWPs with shrouded or otherwise protected controls are available. Keeping the platform tidy will reduce the risk of the operator tripping or losing balance while in the basket.

- **Ground conditions**: The platform should be used on firm and level ground. Any temporary covers should be strong enough to withstand the applied pressure. Localised ground features, e.g. trenches, manholes and un-compacted backfill, can all lead to overturning. If a MEWP is to be used on uneven ground it should be of a type suitable for the task (i.e. rough terrain, with tilt alarm fitted.)
- **Outriggers**: Outriggers must be extended and chocked before raising the platform. Spreader plates may be necessary - check the equipment manual.

- **Guardrails**: Make sure the work platform is fitted with effective guard rails and toe boards.
- **Safe working load**: should be clearly marked on the MEWP and should never be exceeded.

- **Arresting falls**: if there is still a risk of people falling from the platform a harness with a short work restraint lanyard must be secured to a suitable manufacturer provided anchorage point within the basket to stop the wearer from getting into a position where they could fall from the carrier.

- **Falling objects:** barrier off the area around the platform so that falling tools or objects do not strike people below.
- **Weather:** high winds can tilt platforms and make them unstable. Set a maximum safe wind speed for operation. Storms and snowfalls can also damage platforms. Inspect the platform before use after severe weather.
- **Handling materials:** if used to install materials check the weight and dimensions of materials and consider any manual handling and load distribution issues. You may need additional lifting equipment to transport materials to the work position.
- **Nearby hazards:** do not operate a MEWP close to overhead cables or other dangerous machinery or allow any part of the arm to protrude into a traffic route.

Emergency arrangements

Control of an MEWP will normally rest with the operator, in the platform.

Normal and auxiliary control systems built into a mobile elevating work platform(MEWP) will allow the operator to bring the platform of the machine safely to ground level under controlled conditions.

It is extremely unusual not to be able to lower the platform using these controls or for these systems to fail.

In the event of an emergency, however, (for example, the MEWP operator becomes incapacitated) ground controls can be used to safely bring an elevated platform to the ground.

Consideration also needs to be given for emergencies associated with crane operators – in particular tower crane operators.

External conditions, such as adverse weather events or close proximity fire, can also create dangerous situations that require evacuation. Third party rescue can take precious time in an emergency. Portable evacuation kits, such as self-controlled descent line systems, offer crane operators a speedy and safe method of self-rescue.

The safe use of temporary (immobile) access equipment

Trestles

Trestles can be used if the risk assessment shows that the risk of a person falling and injuring themselves is low and the work on top of the trestle is in short bursts.

Steel or aluminium trestles are used in conjunction with scaffold boards or staging. Guardrail systems are available for trestles and you would need to show that installing a guardrail has been looked at and why it was not considered necessary if you do not install them.

Ladders

Ladders and stepladders can be a sensible and practical option for low-risk, short-duration tasks, although they may not automatically be the first choice. Make sure you use the right type of ladder and you know how to use it safely.

Ladders can be used for work at height when a risk assessment has shown that using equipment offering a higher level of fall protection is not justified because of the low risk and short duration of use; or there are existing workplace features which cannot be altered (for example, changing a ceiling mounted light bulb in an office).

Short duration is not the deciding factor in establishing whether the use of a ladder is acceptable or not, the risk also needs to be considered. As a guide, if the task would require staying up a leaning ladder or stepladder for more than 30 minutes at a time, it is recommended that alternative equipment is considered.

Ladders should only be used in situations where they can be used safely, e.g. where the ladder will be level and stable, and where it is reasonably practicable to do so, the ladder can be secured.

Once you have done your 'pre-use' check, the HSE states that "there are simple precautions that can minimise the risk of a fall.

When using a leaning ladder to carry out a task:

- Only carry light materials and tools - read the manufacturers' labels on the ladder and assess the risks.
- Don't overreach - make sure your belt buckle (navel) stays within the stiles.
- Make sure it is long enough or high enough for the task; don't overload it - consider workers' weight and the equipment or materials they are carrying before working at height.
- Make sure the ladder angle is at 75° - you should use the 1 in 4 rule (i.e. 1 unit out for every 4 units up)

Ladder showing the correct 1 in 4 angle

- Always grip the ladder and face the ladder rungs while climbing or descending - don't slide down the stiles.
- Don't try to move or extend ladders while standing on the rungs.
- Don't work off the top three rungs and try to make sure the ladder extends at least 1 m (three rungs) above where you are working.
- Don't stand ladders on moveable objects, such as pallets, bricks, lift trucks, tower scaffolds, excavator buckets, vans, or mobile elevating work platforms.
- Avoid holding items when climbing (consider using a tool belt).
- Don't work within 6 m horizontally of any overhead power line, unless it has been made dead or it is protected with insulation. Use a non-conductive ladder (e.g. fibreglass or timber) for any electrical work.
- Maintain three points of contact when climbing (this means a hand and two feet) and wherever possible at the work position

User maintaining the correct three points of contact

Incorrect - overreaching and not maintaining three points of contact.

- Where you cannot maintain a handhold, other than for a brief period (e.g. to hold a nail while starting to knock it in, starting a screw, etc.), you will need to take other measures to prevent a fall or reduce the consequences if one happened.
- For a leaning ladder, you should secure it (e.g. by tying the ladder to prevent it from slipping either outwards or sideways) and have a strong upper resting point, i.e. do not rest a ladder against weak upper surfaces (e.g. glazing or plastic gutters).
- You could also use an effective stability device.

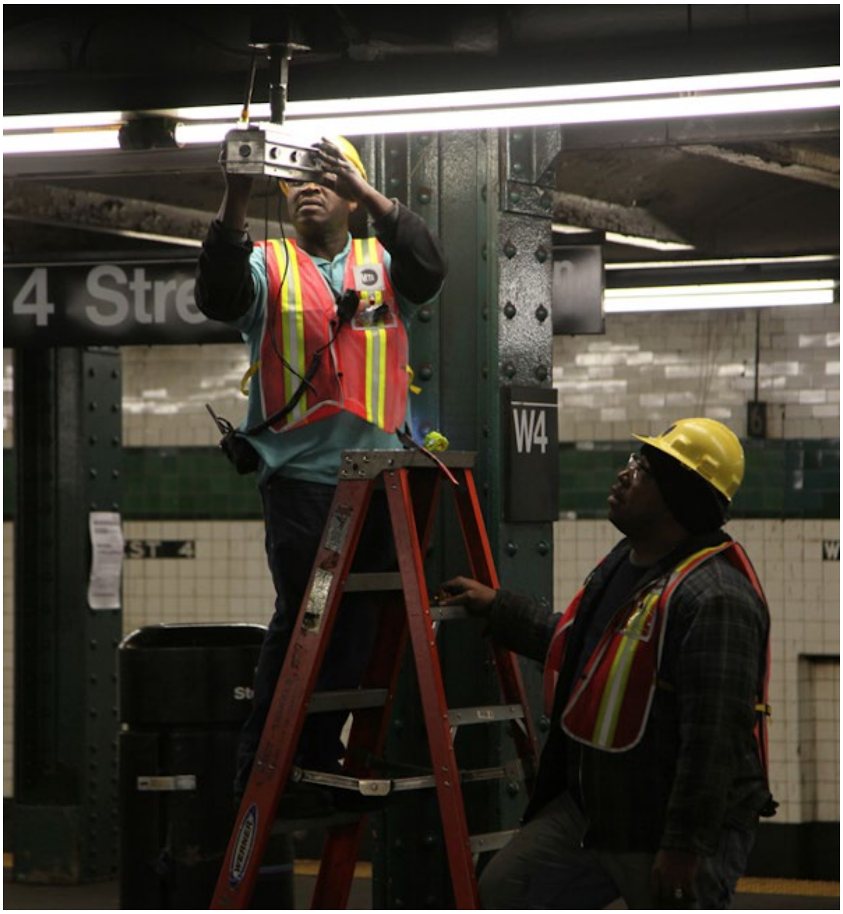
Correct use of stand-off device to ensure a strong resting point.

Step Ladders

When using a stepladder to carry out a task the HSE recommend:

- Check all four step ladder feet are in contact with the ground and the steps are level.
- Only carry light materials and tools.

- Don't overreach.
- Don't stand and work on the top three steps (including a step forming the very top of the step ladder) unless there is a suitable handhold.
- Ensure any locking devices are engaged.
- Try to position the step ladder to face the work activity and not side on. However, there are occasions when a risk assessment may show it is safer to work side on, e.g. in a retail stock room when you can't engage the step ladder locks to work face on because of space restraints in narrow aisles, but you can fully lock it to work side on.
- Try to avoid work that imposes a side loading, such as side-on drilling through solid materials (e.g. bricks or concrete).
- Where side-on loadings cannot be avoided, you should prevent the steps from tipping over, e.g. by tying the steps. Otherwise, use a more suitable type of access equipment.
- Maintain three points of contact at the working position. This means two feet and one hand, or when both hands need to be free for a brief period, two feet and the body supported by the step ladder.



Example of when two hands need to be free for a brief period for lightwork. Keep two feet on the same step and the body supported by the step ladder to maintain three points of contact. Make sure a safe hand hold is available.

When deciding if it is safe to carry out a task on a step ladder where you cannot maintain a hand hold (e.g. to put a box on a shelf, hang wallpaper, install a smoke detector on a ceiling).

This needs to be justified, considering:

- The height of the task
- Whether a hand hold is still available to steady yourself before and after the task
- Whether it is light work
- Whether it avoids side loading
- Whether it avoids overreaching
- Whether the step ladder can be tied (e.g. when side-on working)

Independent Scaffolding

The Constructor website states that "Scaffolding is a temporary frame used to support people and material in the construction or repair of buildings and other large structures. It is usually a modular system of metal pipes, although it can be made from other materials. Bamboo is still used frequently in Asia.

An independent scaffold consists of a double row of standards, with each row parallel to the building. The inner row is set as close to the building as is practicable. The distance between the lines of standards should be the minimum necessary to accommodate the required number of boards and toe boards".

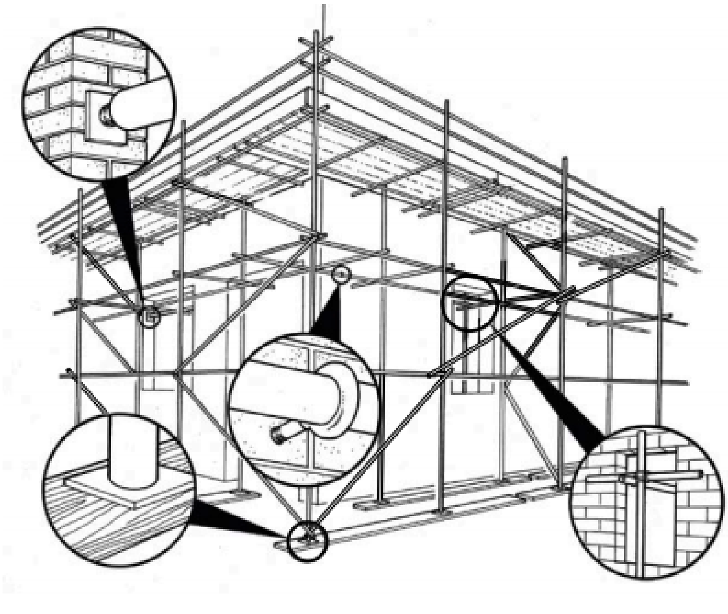


Figure 9 An independent scaffold

Scaffold should only be erected, or altered, by competent persons and should be subject to periodic inspections when in use. This should be according to any national standards. For example, in the UK this is every 7 days.

Tower Scaffolds

Introduction

A tower scaffold is one way to prevent a fall when working at height. The type of tower selected must be suitable for the work and erected and dismantled by people who have been trained and are competent to do so. The prefabricated suppliers and manufacturers association (PASMA) offer such training in the UK.

Those using tower scaffolds should also be trained in the potential dangers and precautions required during use.

Tower scaffold provision and use must be properly managed and, like all scaffolds, include rigorous scaffold inspection arrangements.

Many people are injured each year when they fall from towers or when the tower overturns.

Erection and dismantling

The manufacturer, supplier or hirer has a duty to provide an instruction manual explaining the erection sequence, including any bracing requirements.

Towers should be erected following a safe method of work, either using:

- *Advance guard rail system* - where temporary guard rail units are locked in place from the level below and moved up to the platform level. They are in place before the operator accesses the platform to fit the permanent guard rails.
- *'Through-the-trap' (3T*) - involves the operator taking up a working position in the trap door of the platform, from where they can add or remove the components which act as the guard rails on the level above the platform. It is designed to ensure that the operator does not stand on an unguarded platform.

Stability

To maintain tower stability you must make sure:

- The tower is resting on firm, level ground with the locked castors or base plates properly supported. Never use bricks or building blocks to take the weight of any part of the tower.
- Stabilisers or outriggers are installed when required by the instruction manual
- That a tower is never erected to a height above that recommended by the manufacturer.

Precautions and inspection

Tower scaffolds must comply with the standard required for all types of scaffolds, e.g. double guardrails, toe-boards, bracing and access ladder.

Towers rely on all parts being in place to ensure adequate strength. They can collapse if sections are left out.

All towers must be inspected following assembly and then at suitable regular intervals by a competent person. Work should be stopped if the inspection shows it is not safe to continue, and any faults corrected.

The result of an inspection should be recorded and kept until the next inspection is recorded.

Using and moving

Everyone should be aware of, and follow, these simple rules:

Using:

Never use a tower:

- In strong winds
- As a support for ladders, trestles or other access equipment
- With broken or missing parts
- With incompatible components

Moving:

When moving a tower you should always:

- Reduce the height to a maximum of 4m
- Check that there are no power lines or other obstructions overhead
- Check that the ground is firm, level and free from potholes
- Push or pull using manual effort from the base only
- Never move a tower while people or materials are on the tower, or in windy conditions

Falsework

Falsework is “any temporary structure used to support a permanent structure while it is not self-supporting, either in new construction or refurbishment”.

Any failure of falsework may lead to the collapse of the permanent structure. This could cause injury or death to those working on or near to it, as well as loss of time and money.

The causes of many past failures were foreseeable and could have been prevented by proper consideration when planning, erecting, loading or dismantling the falsework. Investigations into falsework collapses have identified a lack of coordination between the various trades and suppliers of falsework as a major cause.

Failures often occur on simple structures erected by smaller falsework contractors, who may not employ design staff.

All falsework should be designed. This will vary from the use of simple standard solution tables and graphs to site-specific design and supporting drawings. Designs should be checked.

Before erection begins a risk assessment should be carried out and a safe system of work developed. A method statement which includes how all the hazards are to be managed should be prepared. This should be read and understood by those doing the work.

To ensure safety, falsework should be stable at all stages of erection and be regularly checked. Only 'Working Drawings' and not 'Preliminary Drawings' should be used.

Erectors should know:

- Where to start
- Whether the equipment supplied is the same as that ordered
- At what stage checks or permits are required
- Whether checks and permits have already been carried out or issued

Once complete, all falsework should be inspected and certified as ready for use. The frequency of subsequent inspections will depend on the nature of the temporary works. They should be carried out frequently enough to enable any faults to be rectified promptly. National standards may determine frequency.

A competent person should agree the time of striking (removal) for each section of the falsework.

During dismantling, ensure that workers can work safely and cannot be injured by falling objects. A sequence for dismantling should be agreed and detailed.

Safe Methods for Roof Work

Introduction

According to the UK HSE working on roofs is a high risk activity because it involves work at height. In the UK, for example, Roofers account for 24% of all workers who are killed in falls from height while at work. Falls through fragile materials, such as roof lights and asbestos cement roofing sheets, account for more of these deaths than any other single cause. There are also many serious injuries, often resulting in permanent disabilities.

Remember that not all those who are killed or injured while working on roofs are trained roofers - many people accessing roofs are in fact carrying out other tasks, such as maintenance and surveying.

Case Study 1

A roofer was part of a gang who were re-sheeting a large portal frame warehouse. Approximately 50% of the roof was netted underneath. The roofer was moving a sheet from a storage pile at the opposite end of the building when he fell through an uncovered fragile roof light in an area of the roof that was not protected by nets.

Case Study 2

A 50 year old maintenance worker was killed when he fell through a fragile roof light panel as he was checking roof repair work carried out by other contractors. The covers, which had been provided when the repair work was carried out, had been removed and the roof light panels were unprotected.

Weather Conditions

Adverse weather conditions need to be considered when planning for roof work. Rain, ice or snow can turn a secure footing into a skating rink. A roof should always be inspected before work starts to see if conditions have changed and to check whether it is safe to work.

A sudden gust of wind can lead to loss of balance. Roof sheets and, in some circumstances, roofing membrane should not be fixed in windy weather as people can easily be thrown off-balance while carrying a sheet up to or on the roof, particularly when handling large sheeting materials during work on industrial buildings.

Short Duration Work

'Short-duration work' means tasks that are measured in minutes rather than hours. It includes tasks such as inspection, replacing a few tiles or minor adjustment to a television aerial.

It may not be reasonably practicable to install safeguards such as a full independent scaffold or even edge protection for such work, but you will need to provide something in its place.

The decision on the precautions to take will depend on an overall assessment of the risks involved. You should consider:

- Duration of the work
- The complexity of the work
- The pitch of the roof
- The condition of the roof
- Type of roofing material (slate or tile)
- Weather conditions
- The risk to those putting up edge protection
- The risk to other workers and the public

The minimum requirements for short-duration work on a roof are:

- A safe means of access to the roof level
- Safe means of working on the roof, e.g. on a sloping roof, a properly constructed and supported roof ladder; or on a flat roof without edge protection, a harness with a sufficiently short lanyard, attached to a secured anchorage, that it prevents the wearer from reaching a position from which they could fall.

Mobile access equipment or proprietary access systems can provide a suitable working platform in some situations and can be particularly appropriate for short-duration minor work. Where this is not practicable, then work restraint or fall-arrest systems could be considered.

When using fall-protection systems for short-duration roof work, fall protection equipment (used as work restraint) is preferable to fall arrest, as it prevents people falling by physically restricting their movement to a safe area. It should not be possible to reach any unprotected edge, hole or fragile material when relying on this type of system.

Fall arrest is not the same as work restraint. Fall arrest relies on minimising injury once a fall has occurred.

Fragile Roofs

Falling through a fragile roof is one of the main causes of accidents during roof work (Source: UK HSE), occurring in both the construction of new roofs and maintenance of old ones, so it is important to consider fragility when planning any roof work task. Even though the installation of 'non-fragile' roofs, including roof lights, in new buildings is now commonplace.

People who work on roofs should not be complacent, as eventually, even these materials will become fragile due to many factors:

- The fixings were badly secured, leading to excessive wear around the fixing.
- The fixing washers have failed due to over-tightening, leading to sheet and fixing corrosion.
- The protective surface of the profiled sheeting was damaged by foot traffic during construction or during the roof maintenance phase, which will lead to an early breakdown of the sheet's performance.
- Any slip or fall on to the roof may damage the assembly, which could lead to early corrosion failure.
- External atmospheric conditions (e.g. saline or factory processes) may lead to early failure of the sheet's performance
- The sheets and fixings have reached the end of their design performance.

The following are likely to be fragile:

- Old roof lights
- Old liner panels on built-up sheeted roofs
- Non-reinforced fibre cement sheets.
- Corroded metal sheets, either as the primary waterproofing system or as the structural deck supporting a membrane roofing system
- Glass (including wired glass)
- Rotted chipboard or similar
- Wood wool slabs

- Slates and tiles

The hierarchy for work on fragile roofs is:

- Work from underneath the roof using a suitable work platform
- Where this is not possible, consider using a MEWP that allows people to work from within the MEWP basket without standing on the roof itself
- If access onto the fragile roof cannot be avoided, perimeter edge protection should be installed and staging used to spread the load. Unless all the work and access is on staging or platforms that are fitted with guard rails, safety nets should be installed underneath the roof or a harness system used
- Where harnesses are used they need adequate anchorage points. They also rely on discipline, training, and supervision to make sure that they are used consistently and correctly

Flat Roofs

Flat roofs are generally accepted as being up to 10° in pitch and are usually waterproofed with a membrane such as felt.

On flat roofs, falls most frequently occur:

- From the edge of a completed roof
- During surveying, inspection or construction
- From the edge where work is being carried out
- Through openings or gaps
- Through surfaces that are, or have become, fragile, e.g. strawboard, unfixed profiled, metal decking, or aged roof lights

Where the design of the roof does not provide permanent edge protection, such as solid parapet wall of at least 950 mm in height, temporary edge protection will be required.

These should, when erected:

- Give protection for the full duration of the work
- Be strong and rigid enough to prevent people from falling and can withstand other loads likely to be placed on it
- When fixed to a structure, the structure should be capable of supporting it
- Be designed in such a way that it is not necessary to remove it to work at the edge of the roof

https://www.hse.gov.uk/pubns/priced/hsg33.pdf

Where limited work is being carried out on sections of a large roof, and edge protection around the whole perimeter is not reasonably practicable, a simple form of continuous physical barrier some distance from the roof edge could identify the work area and any access route to it.

The distance should be adequate to make sure that people working within the demarcated area cannot fall from the edge of the roof. Where this method is used on roofs with a slight slope, it may be necessary to prevent materials rolling away beyond the 'safe' area. In most circumstances, a distance of at least 2 m from the edge will be sufficient.

Sloping Roofs

The UK HSE states that on traditional pitched roofs, most falls occur:

- From the eaves
- From the roof, typically slipping down the roof, then falling from the eaves
- From the roof, falling internally, e.g. during roof truss erection, stripping roofs, installing membranes and re-roofing
- From gable ends

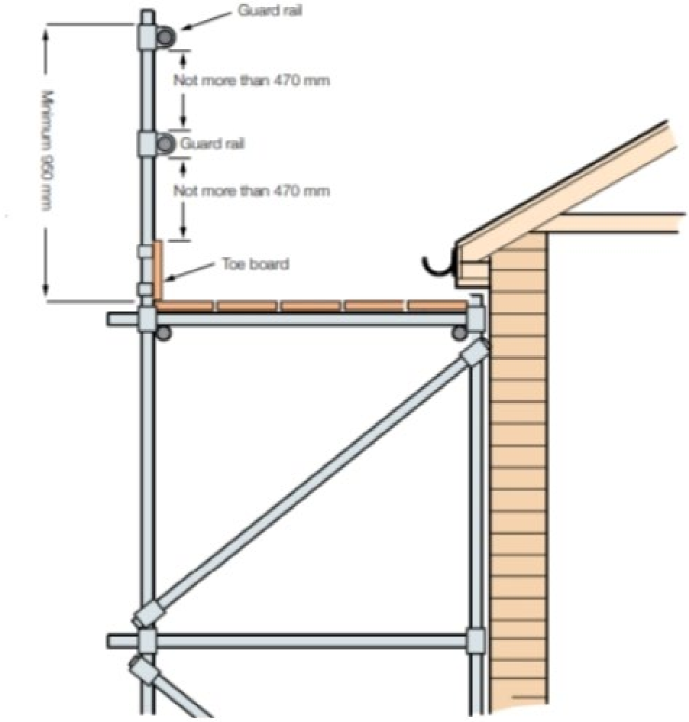
Falls from sloping roofs are more likely if the pitch is steep if the surface is slippery and in windy conditions. Moisture, ice, snow, moss, and lichens all increase the risk of slipping.

For work on sloping roofs, unless of very short duration, full edge protection is required on all roof elevations to which access is needed. This is to prevent people and materials falling from the lower edge of the roof. The potential loading on edge protection when a person slides down a pitched roof onto it is much greater than when falling against it on a flat roof. Make sure that the scaffold supplier knows the roof pitch when you specify edge protection.

If work on the roof requires access within 2 m of gable ends, then edge protection will be needed at those edges. At gable ends there should be one or more working platforms between the eaves height and the ridge. The distance from the highest working platform to the ridge should be no more than one lift high.

A scaffold platform at eaves level provides a good standard of edge protection, a working platform and storage space for materials. The working platform should be as close as possible to the eaves and is recommended to be no greater than 300 mm below eaves level. Brick guards will be necessary if materials, e.g. roof slates, are stacked

above toe board height. They can also reduce gaps between guard rails but need to be designed for this purpose (taking account of the pitch of the roof) and securely fixed.



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Means of Temporary Access - Boatswain's Chairs and Rope Access Systems

A boatswain's chair is a device used to suspend a person from a rope to perform work aloft. Originally just a short plank or swath of heavy canvas, many modern boatswain's chairs incorporate rigid seats.

Rope access systems use two ropes, a working rope and a safety rope, each secured to a reliable anchor. The user's harness is attached to both ropes in such a way they can get to and from the work area and the risk of falling is prevented or limited. This type of system could be used to access the side of a tall building where a cradle cannot be used.

Both systems should be considered for use only when it is not practical to provide a work platform with handrails and toe boards (such as scaffold or MEWP) and will usually be used for light, short duration work (for example, inspection or painting.).

The devices should have the relevant test certificates to confirm fitness for purpose before use. They should be secured to a suitable anchorage point by a competent person. The safe working load should be established before use, and the user trained and competent to operate it.

In use:

Employers will need to make sure that people using the equipment:

- Are competent to check their equipment for defects and do this before every use
- Are suitably trained and assessed for competency in the use of their personal fall protection systems and equipment for the application
- Have read and understood the product information before using the equipment
- Have checked that the components in the system are compatible

Employers will need to arrange for checks and inspections:

- New equipment should be checked to make sure it is appropriate for the intended use, that it operates correctly and that it is in good condition
- All equipment should be checked before each use
- In addition to pre-use checks, equipment should have a detailed inspection by a competent person in accordance with a schedule drawn up by them
- Interim inspections should be made between the inspections by the competent person where a hazard that could cause significant deterioration in the equipment is present, e.g. use in acidic or alkaline environments
- Damaged equipment must be taken out of service immediately

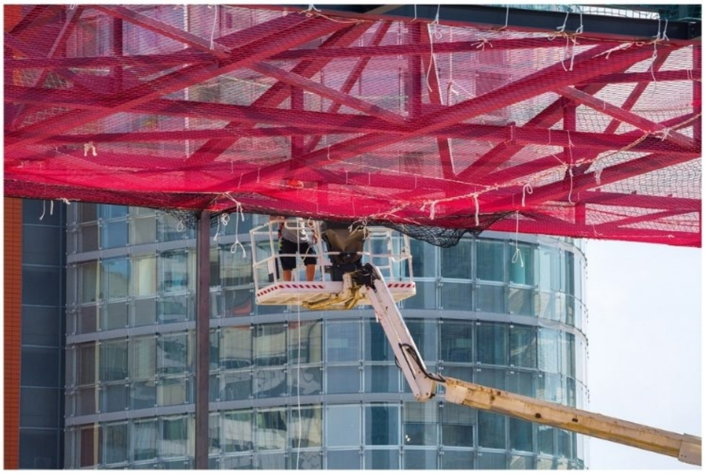
Employers will also need to make sure:

- Anchors and anchor points are of adequate strength
- Where possible, anchors and anchor points are above the user so that the anchor line or lanyard is taut or has as little slack as possible
- There is a rescue plan in place and suitable people and equipment available to put it into effect

Use of Personal and Collective Fall Arrest Devices

Safety Nets

Safety nets are designed to provide passive fall protection without any active or cognisant effort on the part of the user. They are designed with mesh strong enough to withstand the force of people falling into the net, and of an appropriate size to avoid any faller suffering undue physical harm from contact with the net.



Air bags

Air bags perform a similar task as a safety net, acting as both shock absorber and protection against the effects of a fall.

The mat is vented, to provide a constant airflow at all times; this reduces the 'bounce' factor when persons fall into the mat and combats over-inflation and stresses on adjacent structures/surfaces. Again, the installation by a competent person and regular inspections are crucial.

Bags can also be of the "soft" type. Where they are filled with a bean bag type material to cushion a fall.

Belts and harnesses

Simplifiedsafety.com state that "safety belts (worn around the waist and attached to a lanyard) are seldom used these days. Their use is as a fall restraint, not a fall arrestor (for example a belt with a short lanyard may be attached to an anchorage point in a MEWP to stop the operator from climbing on the handrails.)

Full body harnesses are designed, in the event of a fall, to spread the impact across the whole body, not in a small area of the lower back as is the case with a belt. In addition to distributing force, the design of a full body harness serves to keep an employee upright in a fall. This allows a deceleration device (a "shock absorber" in the harness lanyard) to properly deploy, but also keeps the spine vertical, which is the position in which it can best absorb compressive forces of a fall.

Demolition work

The main hazards and risks from demolition work

Introduction

The main causes of accidents in demolition were established as premature collapse of buildings and structures and falls from working places and access routes. A common cause in many of these incidents was found to be failure to plan the operation at an early stage. Such failure invariably leads to site operatives having to devise their own means of access and methods of work, without the benefit of full information on all the dangers.

Demolition is perhaps the most dangerous construction related activity. Its' safe execution is often complex and technical where expertise is vital. One of the practical problems with ensuring health and safety during demolition is that it can proceed very rapidly; with modern equipment, a great deal can be demolished in a couple of days.

Key hazards and risks associated with demolition activities include:

Falls from height

During demolition activities workers can be injured falling from edges, through openings, fragile surfaces, and partially demolished floors. Clearly these risks are eliminated if the demolition is carried out by machine and without workers having to work off the ground. However, hand demolition will inevitably be required in many cases. The use of good access equipment, such as scaffolding and mobile elevating work platforms, and effective barriers around holes in floors or unguarded edges should minimise the risks.

Falling materials

Workers and/or members of the public can be injured by flying debris as the demolition progresses or by debris from any premature collapse of structures.

Control measures to minimise the risk include:

- Establishing clearly marked and barriered or fenced off exclusion zones and hard-hat areas
- Covered walkways
- Using high-reach machines
- Reinforcing machine cabs (including fall object protection systems) so that drivers are not injured
- Good supervision and well-trained workers

Connected services

Utility services (such as gas, electricity, water, and telecommunications services) need to be isolated or disconnected before demolition work begins. The Client has a key role to play here by identifying, to the demolition contractor, the locations of the relevant services. If it is not possible to isolate pipes and cables, they must be labelled clearly, to make sure they are not disturbed.

Traffic management

Effective traffic management systems are essential on site, to avoid putting workers at risk of being hit by vehicles turning, slewing, or reversing. Where possible, vision aids and zero tail swing machines should be used. Banksmen to direct machinery operations may also be required.

Hazardous materials

Dust, asbestos and respirable crystalline silica (RCS) are amongst the hazardous materials that need to be considered as part of the pre-demolition planning (This should be included in any Health and Safety file that exists for the structure.) There may also be other residual material or contamination on site that has not cleared away.

For example:

- Acids from industrial processes
- Flammable liquids
- Unidentified drums
- Microbiological hazards (especially in old hospital buildings)

Noise and Vibration

Demolition activities, where hand or machine demolition is carried out, are inherently noisy. The use of hydraulic breakers or jack hammers by hand carries the added risk of vibration related health issues. Both need to be risk assessed prior to the start of demolition.

Fire

Fire is a risk where hot work (using any tools that generate spark, flame, or heat) is being carried out. For example, cutting up steelwork with oxy acetylene equipment or using thermal lances to melt steel or concrete.

During structural alteration, the fire plan must be kept up to date as the escape routes and fire points may alter. There must be an effective way to raise the alarm.

The main controls for demolition work

Planning, Structural Surveys, and Surveys for Hazardous Substances

Pre-demolition surveys are an essential part of the planning process to ensure the demolition can be done safely.

A thorough structural survey and assessment is required, by a competent person, before any potentially load-bearing parts of a structure are altered or removed.

The structural survey should consider:

- The age of the structure
- Previous use
- Type of construction
- Any nearby buildings or structures

This information is used to determine the steps that are required to ensure that the demolition proceeds without any unintentional or premature collapse.

In addition, the pre-demolition survey should consider the presence of hazardous substances. For example, asbestos, leaded paint, Polychlorinated Biphenyls (PCB's). PCB’s are highly toxic substances which were used as dielectric filler fluids in electrical transformers and capacitors.

The Clients will have an input into the pre-demolition surveys by providing, for example, any existing health and safety file information and/or asbestos register, together with specific information on the likely presence, and nature of, any residual hazardous substances.

Provision of Working Places and Means of Access/Egress

The very nature of demolition work means that workplaces are frequently changing.

Workplaces inside a building, for example, that were initially safe may be rendered unsafe by the removal of an external wall or part of a floor. In such circumstances temporary handrail barriers may need to be erected. Temporary structural supports may be required.

Personnel not involved in the work should be kept away from the work by the provision of a clearly marked exclusion zone around the work area (barriers and/or fencing).

Fans or covered walkways may be necessary to prevent materials from falling into areas where people are working or passing through.

Operatives should be segregated from site plant to ensure they are not at risk from reversing vehicles or slewing excavators. Where possible, vision aids and zero tail swing machines should be used.

Method Statements and Permits to Work

The option when developing a safe system of work is to choose a method of working that keeps people as far away as possible from the risks. Method statements are often used to document the agreed working methods.

Although not required by law, method statements have proved to be an effective and practical management tool. They are especially useful for higher-risk complex or unusual such as demolition. A method statement draws together the information compiled about the various hazards and the ways in which they are to be controlled for any job from the conclusions of the risk assessments. The method statement describes, in a logical sequence, exactly how a job is to be carried out, and includes all the necessary control measures to ensure that the job is carried out safely and without risks to health.

The method statement is an effective way of providing information to employees about how the work is to be carried out and the precautions that should be taken. Effective health and safety method statements often have diagrams incorporated to make it clear how work should be carried out.

Permits to Work may also be used to control high risk activities associated with demolition activities. For example, entry into confined spaces such as sewers, or hot work associated with demolition associated with process pipe work which may have contained flammable materials. In such cases, the permit to work is often issued by a client's representative who has detailed knowledge of the area where demolition is taking place.

Security of Site Boundaries and Protection of the Public

Demolition activities must be carried out without putting members of the public at risk. Children are attracted to construction sites and in particularly the variety of machinery contained therein.

The site boundary will usually consist of suitable fencing, with controlled access for workers and vehicles. The type of fencing will be reflected by the nature of the work and its surroundings. For example, a small demolition job in a remote area may only warrant temporary metal fencing, whereas a large demolition job close to a school may warrant substantial, heavy duty fencing.

Once in place, boundaries must be inspected and maintained. Particular hazards that may affect the public include:

Falling objects - These should not be allowed to fall outside the site boundary. On scaffolds this can be achieved by using toe-boards, brick guards and netting. Fans and/or covered walkways may also be required.

Delivery and other site vehicles - Arrangements need to be in place to prevent pedestrians being struck by vehicles entering or leaving the site.

Scaffolding and other access equipment - The risk to people outside the boundary needs to be considered when erecting, dismantling, and using scaffolding and other access equipment.

Storing and stacking materials - The risks associated with the storage of materials can be reduced by storing materials within the site perimeter, preferably in secure compounds or away from the perimeter fencing.

Openings and excavations - People can be injured if they fall into excavations, manholes, stairwells or from open floor edges. Barriers or covers should be in place.

Excavations

The hazards associated with excavation work

Introduction

Digging foundations and trenches for drains is one of the first jobs carried out on a construction site, and unhappily for some it is the last that they carry out. Workers with many years' experience of excavation work are often deceived by the appearance of ground which they are convinced will stand with little or no support, for as long as they must work in it. There is almost no ground which can be relied upon to stand unsupported in all circumstances.

Every year too many construction workers are killed and maimed when part of inadequately supported excavations, in which they are working, collapse. The risk is self-evident when you consider that one cubic metre of soil can weigh as much as one tonne, and it is quite common for that volume of soil to collapse into an unsupported excavation.

Never forget that in addition to loss of life, and suffering inflicted on the victim's family, such accidents also cost all involved, whether directly or indirectly, considerable financial loss.

Ground movement

Excavations in non-cohesive loose sand and gravel, soft clays, and silts, will require close sheeting to prevent ground movement. The support must be positioned as soon as possible. The use of sheet piles or trench sheeting driven prior to excavation will be necessary in many cases.

Excavations in cohesive soils and in weak rock may stand unsupported for periods ranging from 30 seconds to 30 days. But beware, they are not safe places to work for there is no way of knowing when excavations in ground of this nature will collapse, possibly with fatal consequence. Support is needed to prevent collapse and to ensure the safety of people in and adjacent to the excavation (see figure that follows) Cohesive stiff or very stiff clays may be adequately supported by open or 'hit and miss' trench sheeting where alternate trench sheets are omitted.

Care is necessary when excavating rock which may be fractured, to ensure that loose blocks do not fall from the excavated face, especially where bedding planes dip towards the excavation.

Ground type markedly affects the probability, timing, and the extent and nature of collapse.

The following factors increase the risk of collapse of excavation sides:

- Loose, un-compacted, granular soils, i.e., sand or gravel, or mixtures containing them
- Excavations through different strata, e.g., a weak layer lower down in an excavated face can undermine more stable layers above, such as layers of sand or gravel in otherwise stiff clays
- The presence of groundwater, and the effect on the excavation sides from surface water running into the excavation
- Made-up ground, such as loosely consolidated fill material, old refuse tips, etc
- Proximity to earlier excavations
- Loose blocks of fractured rock
- Weathering, e.g., rain, drying out, freeze/thaw effects
- Vibration from plant, equipment, road, or rail traffic
- Proximity of loaded foundations
- Damage to the support system by personnel, or when materials are lowered into the excavation
- Undercutting of the road pavement structure or kerbs and gullies

Stability of Adjacent Structures

Whenever an excavation is to be carried out close to services or existing buildings or structures, including earthworks such as railway embankments, care should be taken to ensure that the services or foundations of such buildings or structures are not disturbed or undermined.

In all types of soil, some inward movement of the sides of an excavation will occur. Any lateral movement will produce settlement of the surrounding ground, the amount depending on the type of ground and the care taken with the installation of the support.

Settlement may be sufficient to damage adjacent buildings and services. Building foundations that are at less than two times the excavation depth from the face of the excavation are more likely to be affected by ground movement; underpinning of such structures may be necessary to prevent structural damage.

Battering and Stepping (Benching)

Any unsupported excavation will be safe without support only if its sides are battered back sufficiently, or if the excavation is in sound rock. Battering back the sides of an excavation to a safe angle is an acceptable means of preventing instability. In many situations this is the simplest and safest way of ensuring stability and should receive first consideration. In granular soils the angle of slope should be less than the natural angle of repose of the material being excavated. In wet ground a considerably flatter slope will be required.

Methods of Ground Support

The use of proprietary ground support systems offers advantages over traditional systems. Such advantages include:

The ease and improved safety of installation: operatives can install most proprietary ground support systems without the need to enter the excavation

- Systems are available to suit a wide range of applications
- Increased working space for ease of excavation and pipe laying
- The availability of technical advice on selection, installation, and use

The following pages will cover the types of proprietary ground support equipment that are available.

Hydraulic Waling Frames

Comprise two steel or aluminium beams braced apart by struts containing integral hydraulic rams.

They can be used for close or open sheeting applications in trenches and for supporting close sheeting in deep excavations for which frames at various levels may be required.

Trench Boxes

Trench boxes consist of modular side panels strutted apart by adjustable struts to suit the width of trench. Their height can be increased by the addition of extension panels. The location of the struts is variable within limits, depending on the ground clearance required. The lower edges of the side panels are tapered to form a cutting edge (see the figure that follows). Boxes should be progressively dug in as the excavation work proceeds, or they can be lowered by an excavator or crane into a pre-dug trench.

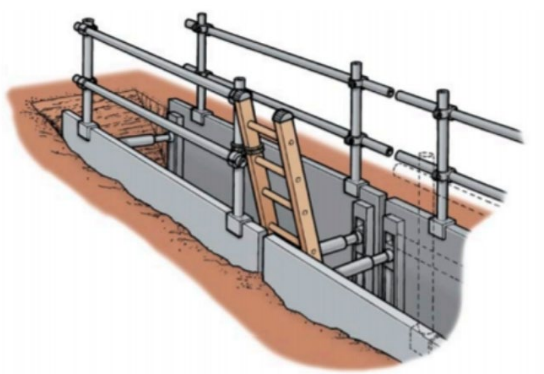
Drag Boxes

Drag boxes comprise two flat-bottomed side panels with tapered cutting edges to their leading ends. They are braced apart by tubular struts; the leading strut being specially strengthened to allow for the dragging of the box by the excavator. As the box is dragged forwards the excavation behind it is left open.

Image courtesy of MGF - Comprehensive temporary works solutions for excavations and above ground structural support www.mgf.co.uk

Traditional Ground Support and its Safe Installation

This is either in the form of timber boards supported by timber walings and struts or props or by steel trench sheeting or sheet piling supported by timber or steel walings and struts.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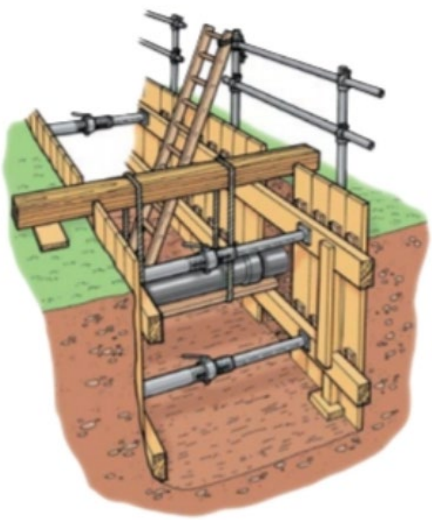
A safe sequence of work for traditional shoring (open sheeting) is:

- Excavate to depth a section of trench the length of a waling
- Place vertical trench sheets at each end of the trench and drive them into the base of the excavation with the excavator bucket
- Install a horizontal waling, along each side of the excavation about 300 mm below ground level by hanging it from the top of the trench sheets
- Working from a lightweight staging (with guard rails affixed) laid across the trench, insert a strut between the walings at the location of the trench sheets
- Install the sheets between the walings and the trench sides and drive into the base of the excavation
- Install intermediate struts as necessary from the lightweight staging (and install edge protection as necessary to prevent people falling into the trench)
- Position a ladder into the excavation, secure, and install lower and intermediate walings as required by the design



https://www.hse.gov.uk/pubns/priced/hsg150.pdf

An excavation supported by timbering and props with guard rails (omitted from left-hand side for clarity) to prevent falls.

Underground Services

Many serious accidents have occurred when buried services have been damaged during excavation work.

Contact with any electricity cables can result in explosion and burns to those in the vicinity.

A man working in a town centre location lost both his arms when he truck a buried 11 kV cable with a pneumatic breaker at 0.5m deep. The existence of the cable was known, and the excavation was within 0.5m of its estimated position. No trial hole had been dug using hand tools.

Escaping gas which ignites can cause serious injury and/or property damage because of fire and explosion. Serious incidents have arisen where gas from damaged pipes has tracked back underground into buildings where it has subsequently ignited.

Excavation should not commence until all available service location drawings have been examined. These should not be considered as completely accurate and serve only to indicate the likely presence of services.

It is therefore essential that service-locating devices (such as cable detectors) are used by properly trained people to identify as far as possible the actual location of underground services. Safe digging practice should then be observed which involves the use of hand tools when near underground services.

Where services cross the line of the trench, they need to be properly supported to prevent damage.

Falls into Excavations

The top of an excavation presents a fall risk to people close by. All excavations more than 2m deep should be provided with suitable barriers.

Edge protection can be achieved in alternative ways if use is made of the support system itself, for example using trench box extensions or trench sheets longer than the trench depth. Where close sheeting is not required, a timber board should be set just into the ground at the rear of the trench sheets to act as a toe-board and to prevent loose material falling into the excavation.

It needs to be remembered that edge protection is required to prevent risk to everyone on site, including workers involved with excavation work, such as those directing vehicles and lifting appliances, and those passing plant and materials in and out of the excavation. Appropraite signage should be put into place.

An elderly member of the public suffered a fractured skull when he fell into a 2.5m deep trench excavated in a main road. No barrier had been placed around the trench.

Heavy plant toppling into an excavation can cause serious injury to those working within it and to the plant operator. Vehicle routes should be carefully planned so that plant does not have to approach close to the edge of an excavation. These routes need to be clearly marked, for instance with baulks of timber and/or fencing. If plant, such

as dumpers or excavators, is used to tip material into an excavation, properly secured stop blocks should be provided to prevent accidental overrunning.

Materials

Workers will be at risk of injury from spoil or stored materials falling into excavations from the surface unless careful control is exercised. Spoil, equipment, and materials should be positioned away from the excavation edge and any edge protection should include toe boards or other means such as projecting trench sheet or box sides. Head protection should be worn.

Inhalation of toxic Gas and Oxygen Deficiency

Consideration should be given to the potential presence, within excavations, of fumes which can cause asphyxiation and/or poisoning. The products of combustion can seep into and collect within trenches if petrol or diesel engine equipment is sited close to the top. (Such equipment should never be taken into an excavation).

Ground such as chalk or limestone in contact with acidic groundwater can liberate carbon dioxide. Glauconitic sand can oxidise, causing oxygen deficiency. Gases such as methane or hydrogen sulphide can seep into excavations from contaminated ground or damaged services in built up areas.

Three workers died from asphyxiation when the manhole they were working in became contaminated with hydrogen sulphide. Initially, only one was affected, then another entered to render assistance. The third worker died when he went to the aid of the first two. The manhole had been connected to a live sewer on the previous day.

The assessment carried out before work commences needs to identify the risk of toxic gas, oxygen deficiency, and fire or explosion. It should also identify the appropriate risk control measures required.

Such as:

- Type of gas monitoring equipment to be provided
- Testing of the atmosphere before entry into the excavation
- Provision of suitable ventilation equipment
- Training of employees
- Use of a sufficient number of people including one at ground level
- Procedures and equipment needed for an emergency rescue

Ground and Surface Water Flow

Depending on the permeability of the ground, water may flow into any excavation below the natural groundwater level. The supports to the side of the excavation should be designed to control the entry of groundwater and the design should take any additional water loading into account. Attention should be given to areas close to lakes, rivers, and the sea.

Water entering the excavation needs to be channelled to sumps from where it can be pumped out; however, the effect of pumping from sumps on the stability of the excavation should be considered. Alternative techniques for de-watering (such as ground freezing and grout injection) could also be used. Designers will need to consider these issues.

The use of 360^{o} Excavators

360° excavators are used extensively in the groundwork phase of construction activities. They consist of a heavy-duty chassis; a fully rotating body (360°); digging gear (jib arm and bucket) and large diameter wheels with pneumatic tyres or a track system.

Most fatal and serious injuries involving excavators occur when the excavator is:

- *Moving* - And strikes a pedestrian, particularly while reversing
- *Slewing* - Trapping a person between the excavator and a fixed structure or vehicle
- *Working* - When the moving bucket or other attachment strikes a pedestrian or when the bucket inadvertently falls from the excavator

Controlling the Risk When Using Excavators

It is important to select the right excavator for the job. There are five main precautions needed to control excavator hazards. These are:

Exclusion: People should be kept away from areas of excavator operation by the provision of suitable barriers. Most excavator related deaths involve a person working near the excavator rather than the driver. Bunting or fencing can be used to create and maintain a pedestrian exclusion area.

Clearance: When slewing in a confined area the selection of plant with minimal tail swing is preferred. Clearance of over 0.5m needs to be maintained between any part of the machine, particularly the ballast weight, and the nearest obstruction.

Visibility: Excavators with the best view around them directly from the driver position should be selected. Excavators should be equipped with adequate visibility aids to ensure drivers can see areas where people may be at risk from the operation of the machine.

Signaller: A signaller should be provided in a safe position to direct excavator operation and any pedestrian movements.

Bucket attachment: Quick hitches can be used to secure buckets to the excavator arm (a quick hitch on an excavator is a latching device that enables attachments to be connected to the dipper arm of the plant and changed quickly.)

Check that you can implement and manage any quick hitch used. Several deaths have occurred in recent years when the bucket has fallen from the machine.

Training and competence: There are three categories of worker who must be trained and competent regarding the excavator hazards and precautions:

Drivers: should be trained, competent and authorised to operate the specific excavator. Training certificates from recognised schemes help demonstrate competence and certificates should be checked for validity.

Signallers: Should be trained, competent and authorised to direct excavator movements and, where possible, provided with a protected position from which they can work in safety.

Pedestrians: Should be instructed in safe pedestrian routes on site and the procedure for making drivers aware of their presence.

The requirements for inspections and examinations of excavations

The following is an excavation inspection regime that is required by UK legislation. Other countries may have their own national regulations which, of course, must be adopted.

Excavations that need to be supported or battered back to prevent danger must be inspected. The person in control of the excavation must arrange for a competent person to carry out these inspections:

- At the start of the shift before work begins
- After any event, likely to have affected its stability
- After any accidental fall of rock, earth or other material

If the competent person is not satisfied that work can be carried out safely, they should advise the person the inspection was carried out for as soon as possible and the excavation should not be used until the defects have been put right.

A written report should be made following most inspections. The competent person must:

- Complete the inspection report before the end of the working period
- Within 24 hours, provide a copy of the report to the person for whom the inspection was carried out

The person receiving the report must:

- Keep it at the site where the inspection was carried out until construction work is completed
- Thereafter, keep it at an office for three months

For an excavation, only one written report is required within any seven-day period, unless there has been a collapse/fall of material or other event likely to affect stability. In this case, an inspection and report are required before work starts again.

The report should contain the following information:

- Name and address of the person the inspection was carried out for
- Location of the place of work or work equipment inspected
- Description of the place of work or work equipment inspected

- Date and time of the inspection
- Details of any matter identified that could give rise to a risk to the health or safety of any person
- Details of any action taken because of any matter identified in the point above
- Details of any further action considered necessary
- Name and position of the person making the report

10.12: Workplace transport and work-related driving

Workplace transport

What should be considered in a workplace transport risk assessment

Introduction

Workplace transport risk assessment is the process of evaluating the risks to a person's safety and health from any vehicle or piece of mobile equipment that is used by an employer, employee, self-employed person or a visitor, in the workplace.

It is the systematic examination of all aspects of work that may be affected by workplace transport and looks at the specific hazards associated with the use of vehicles and mobile equipment in the workplace.

The principle purpose of carrying out a workplace transport risk assessment is to reduce risk.

Stages of the risk assessment

Step 1: Identify the Hazards

Identify and list the **types of vehicles** that use your premises, for instance, employees' cars, forklift trucks, security vehicles, delivery vans, postal vans, large goods vehicles.

Consider less common vehicles that may have to access your premises such as emergency vehicles or waste collection vehicles.

Identify and list the **vehicle activities** and **work activities** associated with the vehicles. Look at:

- How vehicles arrive and depart from the premises. Are there certain times when vehicles arrive?
- Who drives the vehicles? Are there passengers?
- How vehicles travel around the premises.
- How vehicles manoeuvre when on the premises. Where do they park? Do vehicles reverse?
- Areas where people work around moving vehicles or work at height on vehicles. It will also need to consider any movement where members of the public may be evident
- Work activities such as vehicle maintenance, loading and unloading, coupling and uncoupling and load securing activities.
- Normal operation and emergency activities such as vehicle breakdowns.

A site plan or map is useful to identify, in different colours, where vehicular and pedestrian movements occur on site.

Where the vehicles and pedestrian activities intersect, these areas will be high risk and need to be addressed as a high priority.

Step 2: Assess the Risks of Injury or Harm

Identify the risks with each vehicle and activity. Think about what could go wrong.

Identify the people who may be harmed such as employees, customers, contractors, members of the public or visitors to the workplace. Consider how often and how frequently people may be exposed to the hazard.

Think about the three elements of workplace transport safety: the vehicle, the driver and the workplace. Consider could someone:

- Be hit, run over or crushed by a vehicle?
- Fall from a vehicle?
- Overturn a vehicle?

These are the some of the most common causes of workplace transport fatalities. Are there:

- Overhead obstructions on site, such as electrical cables or pipes, could a vehicle hit these?

Take account of certain periods of the day when the number of vehicles and pedestrians moving along routes changes such as shift changes or delivery times.

Do you need to restrict vehicle or pedestrian movements at these times? Consider different times:

- Day time versus night time: Is signage visible at night time? Is the site well lit?
- Summer versus winter: Are there icy or slippery areas on site in winter?

Consider are the vehicles being used for the correct purpose, for instance, a person using a pallet on a forklift to access heights is not correct use of the forklift and such unsafe practices must be prohibited.

Consider how likely it is that the hazard will cause harm and how serious that harm is likely to be. This will help prioritise the risks.

Consult with people like drivers, employees, contractors and visitors during the risk assessment process. They may recognise problems or solutions that you do not see.

Take account of any accidents, incidents or near misses - look at the accident book to see if there have been any previous problems with workplace transport.

Step 3: Control the Risk

Consider what controls are already in place (if any). Are they good enough or should more be done to prevent accident or injury?

Review your workplace, the vehicles, the drivers and your systems of work and compare your controls with existing good practice.

Take account of the general principles of prevention and how they may be applied to workplace transport. For more information on this please click the link below:

Shared Workplaces
Where two or more employers (or the self-employed) share a workplace (whether temporarily or permanently), they need to:

- Co-operate with the other employers so they can meet their health and safety duties.
- Take all reasonable steps to co-ordinate the measures they take to meet any legal duties with those taken by other employers.
- Take all reasonable steps to tell the other employers about risks to their employees' health and safety because of their work activities.

Normally, the site operator or a main employer controls the site and they should take responsibility for co-ordinating health and safety measures by:

- Discussion with the smaller employers.
- Asking other employers to agree to site-wide arrangements.
- Liaising with other employers to help ensure they take responsibility and co-operate.

Where employees enter a different workplace (for example, to make a delivery or collect goods), consider that workplace as shared.

Vehicles on which employees of more than one company are working are also considered shared workplaces, even if it is only for a brief period (for example, during loading and unloading). Both employers are responsible for the safety of their own employees and those of other companies. Those involved in managing this work should agree, preferably in writing, the safety arrangements before work starts.

Providing Information to all Employees and Visitors to Site
The traffic management system must make clear provision for the passing of information to all those affected by traffic movements on site. This includes employees and visitors (such as drivers).

Visiting drivers should report to the site operator for any relevant instructions such as the workplace layout, which route to follow, and where to park, load and unload. They may not have visited the site before and may not be fluent in English so consider, for example, providing a plan of the workplace at the entrance with clear and concise instructions in several languages, possibly including pictures.

It is important for site operators to co-operate with the employers of visiting drivers, to co-ordinate the measures required to help them both meet their health and safety responsibilities.

Why drivers are at risk from fatigue and how fatigue can be managed

The link between fatigue and an increased risk of accidents has been long established. However, with no specific test for how tiredness affects driver behaviour, identifying fatigue as a key contributing factor behind road accidents is problematic.

Whilst organisations that recognise the risk posed by fatigue will have clear rules on driving hours as part of their driver risk management programmes, changing working patterns and issues such as workers having a variety of jobs (such as freelance drivers) mean that employers often have less control over the demands on workers.

The UK HSE defines fatigue as the “decline in mental and/or physical performance that results from prolonged exertion, sleep loss and/or disruption of the internal clock”.

Fatigue causes slower reactions, a diminished ability to process information, reduced awareness and attention, poor co-ordination and a tendency to underestimate risk.

Some (road safety) campaigners argue that excessively tired drivers are as dangerous as those under the influence of alcohol.

Managing the fatigue risk

Actions that organisations can take to reduce the risk of fatigue include:

- Controlling drivers' hours.
- Medical screening and treatment for sleep problems and sleep disorders.
- Fatigue education for drivers.
- Use of "in vehicle" monitoring which assesses slowed blinking and eye movements to see if a driver is fatigued.
- Plan in scheduled rest breaks to driver schedules and encourage drivers to exercise during such breaks.

The use of Telematics

At its core, a telematics system includes a vehicle tracking device installed in a vehicle that allows the sending, receiving and storing of telemetry data. It connects via the vehicle's own onboard diagnostics systems and an onboard modem enables communication through a wireless network.

The device collects GPS data as well as an array of other vehicle-specific data and transmits it to a centralized server. The server interprets the data and enables it to be displayed for end users.

The telematics data captured can include location, speed, idling time, harsh acceleration or braking, fuel consumption and vehicle faults.

Telematics enables accurate information about drivers to be collected, and their driving behaviour to be analysed to identify strengths and weaknesses, crash risk and to create personalised feedback for each driver.

Work-related driving

Managing work-related driving activities

Overview

Work-related road safety encompasses risks faced and created, by people whose job is driving (for example, LGV, PSV drivers) as well as the vast majority of the workforce who drive a vehicle at some point to do their job, for example, driving to an appointment. This includes people who use their own vehicle for work. It also includes anyone who rides a motorcycle or a bicycle for work, and at-work pedestrians, not just those engaged in activities like road works and vehicle recovery but the vast range of people whose jobs bring them into proximity with moving traffic.

Work-related motor vehicle road crashes occur at the workplace and in driving associated with work (excluding commuting). Most work-related crashes involve company cars.

In the United States, Australia, and the European Union, work-related crashes contribute about one quarter to over one-third of all work-related deaths.

Drivers are regularly exposed not only to the dangers of the road but also to a broad range of other hazards, including loading and unloading vehicles, slips, trips and falls, rest and toilet facilities, musculoskeletal and vibration-related disorders, noise, stress, working hours, shift work and fatigue, violence from members of the public, exposure to hazardous substances and lone working.

It is also important to recognise that drivers are not a homogenous group and that they include old, young, women and cross-border workers.

Effective management of work-related road safety helps reduce risk, no matter what size your organisation is. It could also result in, for example:

- Fewer injuries to drivers.
- Reduced risk of work-related ill health.
- Reduced stress and improved morale.

Managing work-related driving activities

The UK HSE's guidance document "Driving at work Managing: work-related road safety (INDG 382)" describes how a 'Plan, Do, Check, Act' can be applied to work-related road safety.

Plan - Describes how you manage health and safety in your organisation and plan to make it happen in practice.

You should:

- Assess the risks from work-related road safety in your organisation.
- Produce a health and safety policy covering, for example, organising journeys, driver training and vehicle maintenance.
- Make sure there is top-level commitment to work-related road safety in your organisation.
- Clearly set out everyone's roles and responsibilities for work-related road safety. Those responsible should have enough authority to exert influence and be able to communicate effectively to drivers and others.

Do - Prioritise and control your risks, consult your employees and provide training and information:

- In larger organisations, make sure departments with different responsibilities for work-related road safety co-operate with each other.
- Make sure you have adequate systems to allow you to manage work-related road safety effectively. For example, do you ensure your vehicles are regularly inspected and serviced according to manufacturers' recommendations?
- Make sure you involve your workers or their representatives in decisions. This is a good way of communicating with them about health and safety issues.
- You must provide training and instruction where necessary.

Check - Measure how you are doing.

- Monitor performance to ensure your work-related road safety policy is effective and has been implemented.
- Encourage your employees to report all work-related road incidents or near misses.

Act - Review your performance and learn from your experience.

- Make sure you collect enough information to allow you to make informed decisions about the effectiveness of your existing policy and the need for changes, for example targeting those more exposed to risk.
- Regularly revisit your health and safety policy to see if it needs updating.